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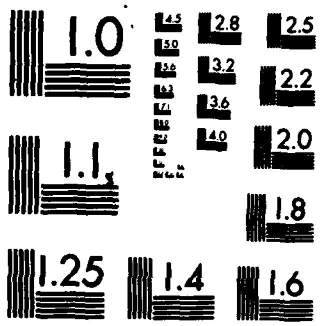

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ELECTRICAL RESISTIVITY OF TEN SELECTED BINARY ALLOY SYSTEMS

By

C. Y. Ho, M. W. Ackerman, K. Y. Wu, T. N. Havill, R. H. Bogaard,
R. A. Matula, S. G. Oh, and H. M. James

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PREFACE

This technical report was prepared by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS), Purdue University, West Lafayette, Indiana, under the auspices of the Office of Standard Reference Data of the National Bureau of Standards (NBS), Department of Commerce, Washington, D.C. It represents the most exhaustive review and critical evaluation of the recorded world knowledge on the electrical resistivity of ten selected binary alloy systems, and is a continuation of a similar work on the thermal conductivity of the same ten binary alloy systems already published. The recommended self-consistent electrical resistivity values presented in this report cover the full ranges of composition and temperature for most of the alloy systems and go far beyond the limited experimental data, which are often conflicting and uncertain in many cases. Thus, new knowledge has been generated in this process of data analysis and synthesis.

This report serves multiple purposes. It provides engineering and design data for virtually all compositions of the ten binary alloy systems for industrial applications at all temperatures. It provides reliable data against which theoreticians can test their theories. Furthermore, the knowledge of the electrical resistivity of binary alloy systems is essential for the study and estimation of the electrical resistivity of ternary and more complex engineering alloys.

Although this report is primarily the result of financial support and interest of the NBS Office of Standard Reference Data, the extensive documentary activity essential to this work was supported by the Defense Logistics Agency of the Department of Defense. Throughout the course of this work, Dr. P. G. Klemens, who is a Visiting Research Professor at CINDAS and Professor of Physics at the University of Connecticut, has given the staff of this project valuable technical guidance and advice; his contributions are hereby gratefully acknowledged. Thanks are also due Dr. H. J. White, Jr., of the NBS Office of Standard Reference Data for his sympathetic understanding and help in many ways.

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ABSTRACT

This work compiles, reviews, and discusses the available data and information on the electrical resistivity of ten selected binary alloy systems and presents the recommended values resulting from critical evaluation, correlation, analysis, and synthesis of the available data and information. The ten binary alloy systems selected are the systems of aluminum-copper, aluminum-magnesium, copper-gold, copper-nickel, copper-palladium, copper-zinc, gold-palladium, gold-silver, iron-nickl, and silver-palladium. The recommended values for each of the ten binary alloy systems except three (aluminum-copper, aluminum-magnesium, and copper-zinc) are given for 27 compositions: 0 (pure element), 0.5, 1, 3, 5, 10(5)95, 97, 99, 99.5, and 100% (pure element). For aluminum-copper, aluminum-magnesium, and copper-zinc alloy systems, the recommended values are given for 26, 12, and 11 compositions, respectively. For most of the alloy systems the recommended values cover the temperature range from 1 K to the solidus temperature of the alloys or to about 1200 K. For most of the nine elements constituting the alloy systems, the recommended values cover the temperature range from 1 K to above the melting point into the molten state. The estimated uncertainties in most of the recommended values are about ±3% to ±5%.

Key words: Alloy systems; alloys; conductivity; critical evaluation; data analysis; data compilation; data synthesis; electrical conductivity; electrical resistivity; metals; recommended values; resistivity.

CONTENTS

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NOMENCLATURE

a, b	Constants in eq (17)
A, B	Constants in eq (20)
c	Impurity concentration; mole fraction; composition
δ_c	Composition error
C	Constant in eqs (3) to (6)
e	Electron charge; base of natural logarithm
$\hbar$	Planck constant divided by 2π
k	Boltzmann constant
$\delta\ell$	Dimensional error
L	Length of specimen at T
L_0	Length of specimen at T_0
ΔL	$\Delta L = L - L_0$
m	Electron mass
M	Atomic weight; net magnetization
N	Electron density
p	Number of positive holes per atom
T	Temperature
T_0	Reference temperature
T_t	Test temperature
U	Quantity defined by eq (15)
v	Electron velocity
V_α, V_β	Volume fractions of α and β phases
z	$z = \hbar\omega/kT$
δZ	Difference in valence
α, β, γ	Positive quantities in eq (10)
Δ	Deviation from the Matthiessen's rule; deviation of $\rho_i(c,T)$ of an alloy from its interpolated value $\bar{\rho}_i(c,T)$

$\delta\Delta$	Change in Δ
ε_F	Fermi energy
θ_D	Debye temperature
θ_R	Characteristic temperature for intrinsic electrical resistivity
κ	Constant
μ	$\mu = \rho_{od}/\rho_{os}$
ν	$\nu = \rho_{id}/\rho_{is}$
ρ	Electrical resistivity
ρ_0	Residual electrical resistivity
ρ_{0b}, ρ_{ib}	Residual and intrinsic electrical resistivities of the belly electrons (those associated with the spherical portions of the Fermi surface)
ρ_{od}	Residual electrical resistivity of the d-bands
ρ_{on}, ρ_{in}	Residual and intrinsic electrical resistivities of the neck electrons (those associated with the portions of the Fermi surface which approach or make contact with the zone boundary)
ρ_{os}	Residual electrical resistivity of the s-bands
$\delta\rho_o$	Increase of residual electrical resistivity
ρ_e	Electrical resistivity due to electron-electron scattering
$\rho_i(T)$	Intrinsic electrical resistivity of a pure metal
$\rho_i(c,T)$	Temperature-dependent part of electrical resistivity of an alloy or impure metal
ρ_{id}	Intrinsic electrical resistivity of the d-bands
ρ_{is}	Intrinsic electrical resistivity of the s-bands
ρ_{sd}	Electrical resistivity due to s-d transitions
ρ_{ss}	Electrical resistivity due to s-s scattering
$\delta\rho_{vac.}$	Increase in electrical resistivity due to vacancies
$\delta\rho_{int.}$	Increase in electrical resistivity due to interstitials
ϕ	Potential energy
$\delta\phi$	Potential energy perturbation

ψ	Wave function
ω	Phonon angular frequency

1. INTRODUCTION

The principal objective of this study was to critically evaluate, correlate, analyze, and synthesize all the available data and information on the electrical resistivity of ten selected binary alloy systems and to generate recommended values over the widest practicable ranges of temperature and alloy composition for each of the alloy systems. This study is a continuation of a similar work on the thermal conductivity of the same ten binary alloy systems [1][1].

The ten binary alloy systems selected are the systems of aluminum-copper, aluminum-magnesium, copper-gold, copper-nickel, copper-palladium, copper-zinc, gold-palladium, gold-silver, iron-nickel, and silver-palladium. These systems include all the three different kinds of binary alloy systems: nontransition-metal and nontransition-metal systems (aluminum-copper, aluminum-magnesium, copper-gold, copper-zinc, and gold-silver), nontransition-metal and transition-metal systems (copper-nickel, copper-palladium, gold-palladium, and silver-palladium), and a transition-metal and transition-metal system (iron-nickel). Most of these alloy systems are among those for which the largest amounts of experimental data are available. However, it will become evident later that even for these alloy systems serious gaps still exist in the electrical resistivity data, as concerns dependence on both composition and temperature, and that some of the available experimental data sets show large uncertainties or wide divergences.

The resulting electrical resistivity values presented in this work are designated as recommended or provisional values depending upon the level of confidence placed on the values and, hence, upon the uncertainty in the values assigned. The uncertainty in the recommended electrical resistivity values is less than or equal to ±5% and that in the provisional values is greater than ±5%. It will be noted that most of the resulting values are designated as recommended values and the uncertainty in the values is generally of the order of ±3% to ±5%.

The recommended electrical resistivity values are based on the room-temperature dimensions of the alloys, as thermal expansion corrections have not been made. This is due to the fact that the available experimental data on the electrical resistivity of the alloys, upon which the recommendations are based,

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[1] Numbers in brackets indicate literature references listed in Section 6.

are not corrected for thermal expansion, and that thermal expansion values for the respective alloys are not available for such corrections to be made. If the values of thermal expansion, $\Delta L(T)/L_0$, for the alloys are available, the electrical resistivity values corrected for thermal expansion, $\rho_{corrected}$, can easily be calculated from the given values uncorrected for thermal expansion, $\rho_{uncorrected}$, by the following relation:

$$\rho_{corrected}(T) = \left\{1 + \frac{\Delta L(T)}{L_0}\right\} \rho_{uncorrected}(T)$$

where $\Delta L = L - L_0$, and L and L_0 are the lengths of the specimen at any temperature T and at a reference temperature T_0, respectively. The thermal expansion correction amounts roughly to about -0.2% to -0.7% at very low temperatures, zero at room temperature, about 0.3% to 0.7% at 500 K, and about 2% near the melting point of the alloy.

The recommended (or provisional) values generated are for alloys which are not ordered and have not been cold-worked severely; the values would be lower for ordered alloys and higher for cold-worked alloys at low temperatures.

The general background information on this work is given in Section 2, which includes a brief summary of the theory of the electrical resistivity of metals and alloys, a short description of the procedure and method used for the data evaluation, correlation, analysis, and synthesis and the generation of recommended values, and a detailed explanation of the specifics and conventions used in the presentation of the data and information.

The experimental data and information and the recommended (or provisional) values for the electrical resistivity of the ten binary alloy systems are presented in Section 3. In the discussion of the electrical resistivity of each alloy system, individual pieces of available data and information are reviewed, details of data analysis and synthesis are given, the considerations involved in arriving at the final assessment and recommendation are discussed, the recommended values and the experimental data are compared, and the uncertainties in the recommended values are stated. For each of the alloy systems except three (aluminum-copper, aluminum-magnesium, and copper-zinc), the recommended values are given for 27 compositions: 0(pure element), 0.5, 1, 3, 5, 10(5)95, 97, 99, 99.5, and 100%(pure element). For aluminum-copper alloy system, recommended values are presented for 26 compositions, without that

containing 80% copper. For aluminum-magnesium alloy system, recommended values are generated only for 12 compositions, lacking those containing 15 to 85% magnesium. Recommended values are given for only 11 compositions of the copper-zinc alloy system, and no values are for those with 35 to 99.5% zinc. For most of the compositions the recommended values cover the temperature range from 1 K to near the solidus temperature (melting starting point). The recommended values have been smoothed simultaneously over both temperature and composition dependences.

The last three sections are for acknowledgments, appendices, and references. There are three appendices given. The first appendix presents, as an example, a detailed account of analysis and synthesis of the electrical resistivity of gold-silver alloy system. A logical organization of the methods for the measurement of electrical resistivity is given in the second appendix. The third appendix presents conversion factors for the units of electrical resistivity, which may be used to convert easily the electrical resistivity values in the SI units given in this work to values in any of the several other units listed.

2. GENERAL BACKGROUND

2.1. Theoretical Background

a. Matthiessen's Rule

It was found experimentally by Matthiessen [2,3] that the increase in the electrical resistivity of a metal due to the presence of a small amount of another metal in solid solution is independent of the temperature. According to this Matthiessen's rule, the total electrical resistivity of an impure metal may therefore be separated into two additive contributions and written in the form

$$\rho(c,T) = \rho_0(c) + \rho_i(T), \tag{1}$$

where ρ_0 is the residual resistivity caused by the scattering of electrons by impurity atoms and lattice defects and is temperature-independent but dependent on the impurity concentration, c, and ρ_i is the temperature-dependent intrinsic resistivity arising from the scattering of electrons by lattice waves, or phonons.

The validity of the Matthiessen's rule has been assessed by Sondheimer [4], who concluded that the maximum deviation should not exceed one percent of ρ_0 in the idealized case in which the impurities do not affect the phonon and electron spectra. However, significant deviations from Matthiessen's rule do occur, which will be discussed in Subsection e. Thus, in general the electrical resistivity of an impure metal is given by

$$\rho(c,T) = \rho_0(c) + \rho_i(T) + \Delta(c,T), \tag{2}$$

where Δ is the deviation from the Matthiessen's rule.

In separating the electrical resistivity into its components, the temperature dependent part sometimes includes the electrical resistivity due to electron-electron scattering, ρ_e; indeed, this is thought to be the dominant temperature-dependent term in transition metals at low temperatures.

In what follows, we will first discuss ρ_i, ρ_e, ρ_0, and Δ, then consider the electrical resistivity of nontransition-metal alloys, and finally comment on aspects of the electrical resistivity of transition metals and their alloys. The theory of electrical resistivity of metals and alloys has been the subject of a number of reviews and has constituted a large portion of the material in several books [5-21].

b. Intrinsic Electrical Resistivity

The intrinsic electrical resistivity which is due to scattering of electrons by phonons may be approximated by the Bloch-Grüneisen formula [22-24]:

$$\rho_i = \frac{C}{M\theta_R}\left(\frac{T}{\theta_R}\right)^5 \int_0^{\theta_R/T} \frac{z^5 e^z dz}{(e^z - 1)^2}, \tag{3}$$

where C is a constant characteristic of the metal and proportional to the square of the electron-phonon interaction constant, M is the atomic weight, and θ_R is a characteristic temperature of the metal which characterizes its intrinsic electrical resistivity in the same way as the Debye temperature, θ_D, characterizes its lattice specific heat. The dimensionless variable of integration $z = \hbar\omega/kT$, where $\hbar$ is the Planck constant divided by 2π, ω is the phonon angular frequency, and k is the Boltzmann constant. The derivation of eq. (3) is based on the simplifying assumptions that the Fermi surface is spherical, that the conduction electrons can be treated as free in the first approximation, that the spectrum of lattice vibrations is that of the Debye model, that the phonon distribution is essentially undisturbed by the scattering processes, and that electron-phonon Umklapp processes can be ignored. Consequently, it is perhaps most reasonable to expect the Bloch-Grüneisen formula to agree with experiment in the case of monovalent metals. Nevertheless, the intrinsic resistivity of many metals can be well represented by eq. (3) over a wide temperature range by a suitable choice of θ_R and C, though no single value of θ_R can fit the data at all temperatures.

At low temperatures ($T \le \theta_R/20$), eq. (3) reduced to

$$\rho_i = \frac{124.4C}{M\theta_R}\left(\frac{T}{\theta_R}\right)^5, \tag{4}$$

while at high temperatures ($T > \theta_R$), to a good approximation, it reduces to

$$\rho_i \approx \frac{C}{4M\theta_R}\left(\frac{T}{\theta_R}\right). \tag{5}$$

Thus it agrees with the experimental facts that at low temperatures (but above about 20 K) the electrical resistivity of some metallic elements is proportional to T^5, and at high temperatures the resistivity of most metals increases approximately linearly with temperature.

The intrinsic resistivity of a metal at the characteristic temperature, $T = \theta_R$ in eq. (3), is

$$\rho_i(\theta_R) = \frac{C}{M\theta_R} \int_0^1 \frac{z^5 e^z dz}{(e^z - 1)^2} = \frac{0.2366C}{M\theta_R} . \tag{6}$$

Combining eqs. (3) and (6) yields the reduced intrinsic resistivity equation

$$\frac{\rho_i(T)}{\rho_i(\theta_R)} = 4.226 \left(\frac{T}{\theta_R}\right)^5 \int_0^{\theta_R/T} \frac{z^5 e^z dz}{(e^z - 1)^2} , \tag{7}$$

which gives a single curve for all metals. The values of the reduced intrinsic resistivity from eq. (7) as a function of the reduced temperature, T/θ_R, have been compared favorably with the experimental data for a number of metals [25,26].

c. Electrical Resistivity due to Electron-Electron Scattering

As in the case of the scattering of electrons by phonons, electron-electron collisions are of two types: normal processes, in which the total wave vector is conserved, and Umklapp processes in which the total wave vectors before and after the collision differ by a reciprocal lattice vector. On the other hand, unlike electron-phonon Umklapp processes, electron-electron Umklapp processes are not frozen out at low temperatures.

Normal processes, involving the collision between two s-band conduction electrons, do not contribute directly to the electrical resistivity because they do not change the total momentum and thus have no effect on the current. Normal processes involving the scattering of an s-band conduction electron by a non-conducting d-band electron do contribute to the electrical resistivity, and are thought to be the dominant temperature-dependent resistive processes in transition elements and their alloys at very low temperatures, since their resistivities show the T^2 temperature dependence expected for electron-electron scattering rather than the T^5 temperature dependence expected for the intrinsic resistivity. This temperature dependence of the electrical resistivity due to electron-electron scattering:

$$\rho_e \propto T^2 \tag{8}$$

comes about through the double application of the exclusion principle in the scattering processes; it applies to both the initial states and final states. For simplicity assume all the states with energies less than the Fermi energy, ε_F, to be occupied and consider the scattering of electron 1, in an excited state of energy greater than ε_F by ε_1, colliding with electron 2 having energy less than ε_F by ε_2. Then conservation of energy requires that ε_1 be greater than ε_2, since the final states must be empty and, therefore, must have energies greater than ε_F. Thus, the orbital of electron 2 must lie within a shell of thickness ε_1 within the Fermi surface so that only a fraction, $\varepsilon_1/\varepsilon_F$, of the electrons can scatter electron 1. Further, the final states must also lie within a shell of thickness less than ε_1 outside the Fermi surface so that only a fraction, $\varepsilon_1/\varepsilon_F$, of the final states compatible with conservation of energy and momentum are allowed by the exclusion principle. The average energy of an occupied excited state measured from ε_F is approximately kT so that $\varepsilon_1/\varepsilon_F \simeq kT/\varepsilon_F$ and the effect of the double application of the exclusion principle is to reduce the collision cross section for electron-electron scattering by a factor $(kT/\varepsilon_F)^2$ below its value for a screened Coulomb interaction.

Umklapp processes between two conduction electrons do contribute to the electrical resistivity. Because these processes involve a reciprocal lattice vector, the wave functions of the electrons involved cannot be regarded as sample plane waves, but must be treated as true Bloch functions having the periodicity of the lattice. The result of this is to introduce into the expression for the resistivity the square of an interference factor. Apparently this factor is quite small, as the low temperature electrical resistivity of most ordinary metals does not show the T^2 temperature dependence expected for such a resistive mechanism; however, a contribution proportional to T^2 has been observed in the liquid-helium-temperature resistivity of indium and aluminum.

d. Residual Electrical Resistivity

The electrical resistivity of a metal or an alloy approaches a constant value, the residual electrical resistivity, as the temperature decreases toward absolute zero. Exceptions to this rule are the phenomena of superconductivity, which are not considered here. The residual resistivity is due to the scattering of electrons by foreign atoms and lattice defects such as vacancies, interstitials, dislocations, and stacking faults.

The most important contribution to the residual resistivity is the scattering of electrons by foreign atoms, which will be discussed in Subsection f in connection with the electrical resistivity of alloys.

Electrical resistivities due to vacancies and interstitials have been estimated theoretically, and studied experimentally by using neutron-irradiated samples. The increase in the resistivity due to vacancies, $\delta\rho_{vac.}$, and that due to interstitials, $\delta\rho_{int.}$, have been given for copper by Blatt [20] as follows:

$$\delta\rho_{vac.} = 1.0 - 1.5 \times 10^{-8}\ \Omega\,\text{m/atomic percent}$$

$$\delta\rho_{int.} = 0.5 - 1.0 \times 10^{-8}\ \Omega\,\text{m/atomic percent.}$$

Dislocations scatter electrons weakly; however, it is sometimes energetically favorable for a dislocation to dissociate into two partial dislocations separated by a ribbon of stacking faults which, particularly if it is wide, may be effective in scattering electrons. Thus, the resistivity due to dislocations is often significantly larger than predicted by theoretical calculations, which may be caused by the substantial contributions of stacking faults and the core of the dislocation line to the resistivity of plastically deformed metals.

Calculation of the resistivity due to stacking faults is difficult and requires a knowledge of the Fermi surface. However, Howie [27] was able to account for the resistivity of a deformed copper specimen in terms of a reasonable density of stacking faults.

e. Deviations from Matthiessen's Rule

For Matthiessen's rule to be exact, the scattering of electrons by imperfections and by phonons would have to be independent of each other, and this is only approximately true. Other causes for deviations from Matthiessen's rule are as follows:

(1) Alloying may alter the band structure of the metal.

(2) Alloying may change the phonon spectrum or perturb the phonon distribution in the steady state.

(3) There may be parallel conduction by two bands of electrons.

The first two effects are to be expected in concentrated alloys, but two-band effects can cause significant deviations in multivalent elements and in very dilute alloys of monovalent elements.

The two-band effect was first discussed by Sondheimer and Wilson [28], who considered the case in which the s- and d-bands of electrons of a transition element conduct in parallel. They found that if ρ_0 depends only on ρ_{0s} and ρ_{0d} of the s- and d-bands, respectively, and ρ_i depends only on ρ_{is} and ρ_{id}, then the deviation from Matthiessen's rule is given by

$$\Delta = \rho - \rho_0 - \rho_i = \frac{\rho_{0s}\,\rho_{is}(\mu - \nu)^2}{(1 + \mu)(1 + \nu)[\rho_{0s}(1 + \mu) + \rho_{is}(1 + \nu)]}, \tag{9}$$

where $\mu = \rho_{0d}/\rho_{0s}$ and $\nu = \rho_{id}/\rho_{is}$. Thus, there is a positive deviation unless these ratios are equal. At low temperatures ρ_{is} is smaller than ρ_{0s} so that Δ is approximately proportional to ρ_{is} and thus to ρ_i, while at high temperatures ρ_{is} is larger than ρ_{0s} so that Δ is approximately proportional to ρ_{0s} and thus to ρ_0. It follows that Δ increases from zero at zero temperature to a constant value proportional to ρ_0 at high temperatures. When ρ_0 and ρ_i are of the same order of magnitude, the deviation can be approximated by

$$\Delta = \frac{\alpha\,\rho_0\,\rho_i}{\beta\,\rho_0 + \gamma\,\rho_i}, \tag{10}$$

where α, β, and γ are positive quantities of the order of unity [6, p. 312]. Taking α, β, and γ equal to unity it follows that the largest relative deviation, $\Delta/(\rho_0 + \rho_i)$, occurs when ρ_0 and ρ_i are equal.

Dugdale and Basinski [29] explained the deviations from Matthiessen's rule observed in dilute copper alloys and silver alloys on the bases of an argument by Ziman [30] concerning the different anisotropies of relaxation times for phonon and impurity scattering. While their expression for Δ is equivalent to that obtained by Sondheimer and Wilson, the interpretation and temperature dependence are quite different.

Ziman divided electrons into two groups: (1) the belly electrons associated with the spherical portions of the Fermi surface and (2) the neck electrons associated with the portions of the Fermi surface which approach or make contact with the zone boundary. The electron-phonon interactions responsible

for ρ_i are of two types: normal processes in which the sum of the wave vectors remain unchanged, and Umklapp processes in which the sum of the wave vectors changes by a reciprocal lattice vector. In the case of belly electrons, Umklapp processes can take place only with phonons having a minimum wave vector and minimum energy determined by the differences between the belly electron wave vector and the nearest wave vector in the next Brillonin zone. At low temperatures such phonons disappear and the Umklapp processes involving belly electrons are frozen out. On the other hand, the neck electrons have wave vectors arbitrarily near to the zone boundary and Umklapp processes can occur at both low and high temperatures. Thus, while the strength of the electron-phonon interactions may be about the same for the two groups at room temperature and above, at low temperatures they are much stronger on the neck than on the belly so that the ratio ρ_{ib}/ρ_{in} increases from a small value at low temperatures to a constant value at room temperature and above. Ziman considered impurity scattering in the cases of silver in gold and of copper in gold. In the first case the atomic volumes are very nearly equal and the effect of silver atoms on the conduction electrons is due only to differences in the effective potential in the ion core, consequently the belly electrons, which have wave functions that are large in the region of the core, will be strongly scattered, while the neck electrons, which have wave functions that are large only in the region between the cores, will be weakly scattered. In the second case the atomic volumes are very different, and the effect of the copper atoms on the conduction electrons is much like that of a charged impurity, a change in the potential extending out into the region between the ion cores, so that the neck electrons are also scattered strongly.

It follows from the above that on this model if the ratio ρ_{ib}/ρ_{in} is always smaller than the ratio ρ_{0b}/ρ_{0n}, then Δ rises from zero at zero temperature, goes through a maximum, and takes on a constant value at high temperatures; this is the behavior observed in the dilute Cu + Au and Ag + Au alloys investigated by Dugdale and Basinski.

The deviations from Matthiessen's rule in iron alloys [31] and nickel alloys [32] have been explained in terms of parallel conduction by the spin-up and spin-down electrons. At low temperatures there are few interactions between the electrons of opposite spin, so that an electron with its spin in a given direction emerging from an impurity collision will reach the next impurity with

its spin unchanged; thus an impurity resistivity can be defined for each group. If the impurity relaxation time is considerably longer for one group of electrons than for the other, the scattering of electrons of that group will contribute relatively little to the residual resistivity. At high temperatures, on the other hand, there may exist (presumably as a result of electron-electron collisions) a process of spin mixing in which the electrons change their spin directions a number of times between impurity collisions. There will then be no group of electrons that experience relatively small impurity scattering, and the high-temperature impurity resistivity will become considerably greater than the low-temperature residual resistivity.

Deviations from Matthiessen's rule have been comprehensively reviewed by Bass [33] and by Cimberle et al. [34].

f. Electrical Resistivity of Alloys

Alloying affects the electrical resistivity of the host metal drastically, since it causes lattice perturbations, modifies the lattice-vibrational spectrum and electronic band structure, changes the Fermi energy and electronic density of states, etc.

For the residual electrical resistivity of binary solid-solution alloys containing c mole fraction of element A and (1 - c) mole fraction of element B, Nordheim's rule [35] is

$$\rho_0 \propto c(1-c). \tag{11}$$

This rule is applicable only to homogeneous random (not ordered) solid solutions of two metals which are not transition elements. It is apparent from eq. (11) that ρ_0 is directly proportional to c if c << 1.

Nordheim's rule can be made plausible by the following argument. The average cellular potential for a binary alloy with mole fraction c of element A in element B is given by

$$\phi = c\phi_A + (1-c)\phi_B \tag{12}$$

and the perturbations of this potential at the sites of the A and B atoms are

$$\delta\phi_A = \phi_A - \phi = (1-c)(\phi_A - \phi_B) = (1-c)\phi_{AB} \tag{13}$$

$$\delta\phi_B = \phi_B - \phi = c(\phi_B - \phi_A) = -c\phi_{AB}\,. \tag{14}$$

In the Born approximation, the scattering cross section per scattering center is proportional to the square of the matrix element of the perturbation. The probability per unit time that an electron will be scattered from state $\Psi_{\underline{k}}$ into state $\Psi_{\underline{k}'}$ by a single A atom is $(1-c)^2\ U^2$ where

$$U = \int \Psi_{\underline{k}'}\ \phi_{AB}\ \Psi_{\underline{k}}\ d^3\underline{r} \tag{15}$$

and $\Psi_{\underline{k}}$ and $\Psi_{\underline{k}'}$ are the initial and final wave functions. The probability per unit time that an electron will be scattered by a single B atom is c^2U^2. Since the fractions of A atoms and B atoms are c and $(1-c)$, the total scattering probability per unit time, and therefore the residual resistivity, is of the form

$$\rho_0 \propto [c(1-c)^2 + (1-c)c^2]U^2 = c(1-c)U^2. \tag{16}$$

This rule is obeyed quite well by many binary alloy systems, but not by those in which either constituent is a transition element.

In dilute solid-solution alloys, Norbury [36] found that the increase of residual resistivity per atomic percent solute, $\delta\rho_0$, increases with the valence difference, δZ, between the solute and the solvent atoms. By analyzing thoroughly the data on this effect, Linde [37-39] concluded that $\delta\rho_0$ is proportional to the square of δZ, i.e.,

$$\delta\rho_0 = a + b(\delta Z)^2, \tag{17}$$

where a and b are constants for a given solvent metal and a given row of the periodic table to which the solute elements belong. This is the Norbury-Linde's rule.

A rough theoretical justification for Norbury-Linde's rule was given by Mott [40], who calculated $\delta\rho_0$ on the assumption that the electrons behave as if they were free and used a screened Coulomb potential to describe the perturbation, and used the Born approximation to calculate the scattering cross section. For a solute in the same row of the periodic table, in which case a is zero, he obtained

$$\delta\rho_0 = \frac{2\pi(\delta Z)^2 e^2}{100\ mv^2}\left[\ln\left(1 + \frac{4m^2v^2}{q^2\hbar^2}\right) - \left(1 + \frac{q^2\hbar^2}{4m^2v^2}\right)^{-1}\right]. \tag{18}$$

Here e, m, and v are the electronic charge, mass, and velocity, q is the screening parameter, and $\hbar$ is the reduced Planck constant. The $(\delta Z)^2$ dependence is obtained because in the Born approximation the scattering is proportional to the square of the matrix element of the perturbation. The Born approximation overestimates the scattering for this type of potential so that eq. (18) is only an approximation; however, fair agreement with experiment can be obtained by taking the screening parameter to be somewhat greater than the usual estimate. Better estimates of $\delta\rho_0$ can be obtained by the more refined phase-shift calculations, but these do not yield the simple $(\delta Z)^2$ dependence.

Norbury-Linde's rule is not obeyed when the alloying involves transition elements or polyvalent elements such as aluminum and magnesium.

Another factor influencing the residual resistivity of alloys is short range order which may either decrease it, as in the case of α brass [41], or increase it as in the case of copper-gold alloys [42,43]. Short range order is increased by annealing and destroyed by mechanical deformation and by heating and quenching.

In the case of binary alloy systems whose alloys are two-phase ($\alpha + \beta$) mixtures, the electrical resistivity of the alloys is equal to the sum of the product of the electrical resistivity of each phase and its volume fraction, i.e.,

$$\rho = \rho_\alpha V_\alpha + \rho_\beta V_\beta , \tag{19}$$

where ρ_α and ρ_β are the electrical resistivities and V_α and V_β are the volume fractions of α and β phases, respectively. Equation (19) is derived by considering the alloy as a rod which consists of a large number of small fibers in parallel, with each fiber having a certain volume of α-phase in series with a certain volume of β-phase.

g. Electrical Resistivity of Transition Elements and Their Alloys

In terms of electronic transport properties, the most important feature of transition elements, at least those having face-centered cubic crystal structure such as nickel and palladium, is the presence of a narrow d-band with a high density of states overlapping the conduction band at the Fermi energy level. As originally suggested by Mott [44], the role of this d-band

is to provide a large number of levels into which the s-electrons can be scattered and lost from the current, thus causing the high electrical resistivity of transition elements as compared with that of ordinary metals.

As palladium is added to silver, the resistivity first increases in the way observed for binary alloys of ordinary metals. At a certain composition, about 40 atomic percent palladium, the number of conduction electrons is no longer sufficient to fill the d-band holes and the resistivity begins to increase rapidly, rising to an asymmetric peak. Mott [44] provided a semi-quantitative explanation of the shape of the curve which may be summarized as follows. The resistivity was taken to be the sum of terms due to s-s and s-d scattering. The resistivity due to s-s scattering was taken to have the composition dependence given by Nordheim's rule while that due to s-d scattering was taken to be proportional to the density of vacant states in the d-band, which in turn was taken to vary in the same way as the paramagnetic susceptibility, that is, as $(p-c)^2$ for $c < p$, and zero for $c > p$ for atomic fraction c of silver in palladium, where p is the number of positive holes per atom in pure palladium. Also, while silver and palladium in the alloy were assumed to have a common s-band, the d-band was assumed to be split into two bands and the one associated with silver atoms was taken to be below that associated with palladium atoms and thus below the Fermi energy level. With these assumptions Mott obtained the following equation for the electrical resistivity of the alloys:

$$\rho = A(p-c)^2(1-c)c^2 + B(1-c)c, \tag{20}$$

where A and B are constants. If A and B are properly chosen, eq. (20) will result in a resistivity-composition curve similar to that observed experimentally for this alloy system.

Coles and Taylor [45] used a similar model to explain the shape of this resistivity-composition curve but derived the density of states of the d-band from the electronic specific heat. Later, Dugdale and Guénault [46] modified Mott's model to make it consistent with the findings of Vuillemin and Priestley [47] concerning the Fermi surface of palladium. With this model they were able to explain not only the shape of the resistivity-composition curve but also the low-temperature thermoelectric power of these alloys.

The temperature dependence of the electrical resistivity of nickel and iron shows an anomaly caused by their being ferromagnetic: while above the Curie temperature the resistivity has the usual concave-downward curvature, below the Curie temperature it is concave upward. This behavior can be explained on the basis of a band model for the d-electrons in terms of s-d scattering, and on the basis of a model in which the d-electrons are localized on their atoms in terms of spin-disorder scattering. Mott and Stevens [48] argued that the former model applied to nickel and the latter to iron.

In the band model the narrow d-band overlaps the s-band. Above the Curie temperature, vacant d-states of both spin directions are present in equal numbers. Below the Curie temperature, there is a greater number of vacant states with spin up in a given domain and the number increases with decreasing temperature, while the number with spin down decreases until at zero temperature all of the spin down states are filled. If only states with spin up are vacant, then a spin-down electron cannot make a spin-conserving transition into the d-band, so that its mean free path is greater than in the unmagnetized state. Assuming that the energy is proportional to the square of the wave vector so that the density of d-states at the Fermi level, $N_d(\varepsilon_F)$, is proportional to the square root of the Fermi energy, noting that the Fermi wave number, is proportional to the cube root of the electron density, one obtains

$$N_{d_\pm}(\varepsilon_F) \propto \left(1 \mp \frac{M}{M_0}\right)^{1/3} , \tag{21}$$

where M is the net magnetization, reaching the saturation value M_0 at T = 0 K, and ± refers to spin up and spin down electrons. Since the reciprocal relaxation time, and thus the resistivity due to s-d transitions, is proportional to $N_d(\varepsilon_F)$, one obtains

$$\rho_\pm = \rho_{ss} + \rho_{sd}\left(1 \mp \frac{M}{M_0}\right)^{1/3} . \tag{22}$$

In an unmagnetized specimen there are many domains in which the magnetization of the d-spin is in different directions so that, instead of having parallel conduction by spin-up and spin-down electrons, both types of electrons see an average resistivity:

$$\rho = \rho_{ss} + \frac{\rho_{sd}}{2}\left[\left(1 - \frac{M}{M_0}\right)^{1/3} + \left(1 + \frac{M}{M_0}\right)^{1/3}\right]. \tag{23}$$

For small M/M_0 this reduces to

$$\rho \approx \rho_{ss} + \rho_{sd}\left[1 - \frac{1}{9}\left(\frac{M}{M_0}\right)^2\right], \tag{24}$$

which is in qualitative agreement with the experimental data for nickel.

If the d-electrons are localized on their atoms, then instead of s-d scattering, the theory proposes an s-d exchange interaction with an energy depending on the relative orientation of the spin of a moving s-electron to that of the fixed d-electron near which it is passing. If the spins of the d-electrons in a domain are lined up parallel, then the electrons would not be scattered, but as the temperature is increased, the d-spins within the domain become disordered, and there is an extra contribution to the resistivity which increases rapidly as the Curie temperature is approached and takes a constant value above the Curie temperature.

Since s-d scattering due to the electron-phonon interaction continues to increase with temperature above the Curie temperature, while the spin-disorder scattering takes on a constant value, the two mechanisms can be distinguished experimentally. Coles [49] predicts the former behavior for a Ni-Pd alloy and the latter behavior for an Fe-Rh alloy.

2.2. Data Evaluation and Generation of Recommended Values

The recommended electrical resistivity values were generated through critical evaluation, correlation, analysis, and synthesis of the available experimental data and information compiled from all sources. The procedure involved critical evaluation of the validity of available data and related information, judgment on the reliability and accuracy of the data, resolution, and reconciliation of disagreements in conflicting data, correlation of data in terms of various controlling parameters, curve fitting with theoretical or empirical equations, and synthesis of the often fragmentary data to generate a full range of coverage of internally consistent "best" values.

In the critical evaluation of the validity and reliability of a set of experimental electrical resistivity data, the temperature dependence of the data was examined, and any unusual dependence or anomaly was carefully investigated. The experimental technique was reviewed to see whether the actual boundary conditions in the measurement agreed with those assumed in the theory, and the estimation of inaccuracies by the authors was checked to ensure that all the possible sources of error were considered. The sources of error might include the inaccuracy in the measurement of specimen dimensions and of the distance between potential probes, uncertainty due to the effect of thermal expansion, inaccuracy in temperature measurement, inaccuracy due to poor sensitivity of measuring devices or circuits, uncertainty at high temperature due to specimen instability or specimen and/or thermocouple contamination, etc. These and other possible sources of error were carefully considered in critical evaluation of experimental data.

The uncertainty of a set of experimental data is caused, however, not only by the experimental error in the measurement, but also by the inadequacy of characterization of the material for which the data are reported. Therefore, in data analysis it should be kept in mind that the total difference between two sets of experimental data is the sum of the difference due to experimental error and the real difference due to sample variance. It was found in this and other studies that the chemical composition of a specimen reported by the author was often unreliable. This might partly be due to the fact that in many cases the stated composition of a specimen was [illegible] at the author obtained from the company who supplied the specimen and it could at best represent only the

nominal composition; the actual composition varied from sample to sample. In other cases there was a strong tendency for only certain particular elements to be detected by a particular chemical analysis which could miss other important constituents. Furthermore, the chemical composition of a specimen might change when it was measured at high temperature.

In many cases research papers did not contain adequate information for performing a truly critical evaluation. In these cases, some other considerations were used for data evaluation. For instance, if several author's data agreed with one another and, more importantly, these were obtained by using different experimental methods, these data were judged to be reliable. However, if the different sets of data were obtained by means of the same experimental method, even though they all agreed, the reliability of the data was still subject to questioning, because they might all suffer from a common, but unknown, source of error. Secondly, if the same apparatus had been used for measurements of other materials and the other results were reliable, the result for the new material was judged also to be reliable. If the information given by the author was entirely inadequate to make any value judgment, the data assessment was subjective. At times, judgments were based upon factors and considerations such as the central purpose of his research, the motivation for his measurement, general knowledge of the experimenter, his past performance, the reputation of his laboratory, etc.

In the process of critical evaluation of experimental data outlined above, unreliable and erroneous data were noted and set aside. The remaining data were then used for data correlation and synthesis, and graphical smoothing was often used. In graphical smoothing of experimental data for a binary alloy system, cross-plotting from electrical resistivity data versus temperature to resistivity data versus composition and vice versa were made. Smooth curves were drawn which approximate the best fit to the resistivity data versus temperature, and points from the smoothed curves were used to construct resistivity-versus-composition curves for a convenient set of selected temperatures. In a resistivity-versus-composition graph, the family of isotherms was similar and any required smoothing of the data could be done more easily and with greater confidence than when working directly with the resistivity-versus-temperature curves. The points from the resulting smoothed curves were then used to construct resistivity-versus-temperature curves for selected compositions, and these curves

were further smoothed. In the graphical smoothing process it was extremely important that the alloy phase diagrams be constantly consulted and the phase boundaries between solid solutions and/or mechanical mixtures and the boundaries of magnetic transitions be kept in mind, so as to be aware of any possible discontinuity or sudden change of slope in the resistivity curves.

In graphical smoothing and synthesis of data for a binary alloy system, instead of cross-plotting the total electrical resistivity, $\rho(c,T)$, it was often better to work with the temperature-dependent part, $\rho_i(c,T)$, of the electrical resistivity, i.e.,

$$\rho_i(c,T) = \rho(c,T) - \rho_0(c). \tag{25}$$

This temperature-dependent part changes more slowly with the alloy composition, c, than does the total electrical resistivity, and its isotherms may form a family more convenient for cross-plotting. Furthermore, for a binary alloy system that forms a continuous series of solid solutions over the entire range of compositions, it has proved very useful to go further in this direction by working with the quantity

$$\Delta(c,T) = \rho_i(c,T) - \bar{\rho}_i(c,T), \tag{26}$$

where $\bar{\rho}_i$ is the atomic-fraction-weighted average of the intrinsic resistivities, $\rho_i^{(A)}$ and $\rho_i^{(B)}$, of the two pure metals A and B:

$$\bar{\rho}_i(c,T) = c\rho_i^{(A)}(T) + (1-c)\ \rho_i^{(B)}(T) \tag{27}$$

with $c \equiv c_A$ of metal A.

Since the quantity Δ is at most a few percent of ρ, irregularities and discrepancies in the values of ρ become very conspicuous in plots of Δ or Δ/T, and this increases the confidence with which one can reject some data as aberrant or unreliable. In the low-temperature region it is better to cross-plot Δ versus T or c, while at high temperature cross-plotting Δ/T versus T or c is preferred. Cross-plotting of Δ is convenient up to 300 K and cross-plotting of Δ/T down to 100 K; the range of overlap in T makes it useful to employ both types of plot in relating low-temperature data to high-temperature data. As an example to illustrate the application of this method and procedure, a detailed account of analysis and synthesis of the electrical resistivity data for the gold-silver alloy system is presented in Appendix 5.1.

Combining eqs (25) to (27) gives an expression for the electrical resistivity of a binary alloy:

$$\rho(c,T) = \rho_0(c) + c\rho_i^{(A)}(T) + (1-c)\ \rho_i^{(B)}(T) + \Delta(c,T). \qquad (28)$$

This expression reduces to eq (2) for an impure metal for which c approaches zero.

2.3. Presentation of Data and Information

In this work, the term "binary alloy system" refers to the full range of composition of two alloying elements and is signified by a hyphen between the two elements, such as aluminum-copper alloy system. The term "binary alloys" refers to a group of binary alloys in which the first alloying element is predominant and is signified by a plus between the two elements, such as aluminum + copper alloys. In specifying the composition of an alloy, weight percent is denoted by % and atomic percent by At.% or at.%.

In each of the subsections in Section 3, electrical resistivity data and information for each alloy system are presented in the following order:

(1) A discussion text,
(2) A table of recommended values given as a function of both temperature and composition,
(3) Two figures presenting recommended values as a function of temperature,
(4) Two comparable figures presenting experimental data as a function of temperature,
(5) Two tables giving measurement information on the experimental data presented in the two figures of item (4),
(6) Two comparable tables tabulating experimental data of all the data sets presented in the two figures of item (4) and/or listed in the two tables of item (5),
(7) A figure presenting both recommended values and experimental data as a function of composition,
(8) A table giving measurement information on the experimental data presented in the figure of item (7), and
(9) A comparable table tabulating experimental data of all the data sets presented in the figure of item (7) and/or listed in the table of item (8).

Thus, there are normally five figures and seven tables for each alloy system, excepting that some additional figures presenting other useful information are also given for a few particular alloy systems.

In the discussion text on the electrical resistivity of each alloy system, individual pieces of available data and information are reviewed, details of data analysis and synthesis are given, the considerations involved in arriving

at the final assessment and recommendation are discussed, the recommended values and the experimental data are compared, and the uncertainties of the recommended values are stated.

In the table of recommended values, those values which are provisional are indicated each by a double dagger (‡). The designation as recommended or provisional values depends upon the level of confidence placed on the values and, hence, upon the uncertainty in the values assigned. The uncertainty in the recommended electrical resistivity values is ±5% or smaller and that in the provisional values is greater than ±5%.

Values in a temperature range where no experimental data are available are indicated each by an asterisk (*). However, it is important to note that in many cases whether experimental data are available or not in a particular temperature range has no bearing on the accuracy or uncertainty in the recommended values generated for that temperature range. It is because in many cases the available experimental data in a particular temperature range are those already rejected as erroneous or unreliable and therefore not used at all in the generation of recommended values for that temperature range, and in many other cases the recommended values for a particular temperature range were generated from accurate values in other ranges and therefore are accurate even though no experimental data are available in that particular temperature range. In other words, recommended values with asterisks *do not* necessarily have larger uncertainty than those without, and in many cases the opposite is true.

The recommended (or provisional) values in some of the tables are given with more significant figures than warranted, which is merely for tabular smoothness or for the convenience of internal comparison. Hence, the number of significant figures given in the table has no bearing on the degree of accuracy or uncertainty in the values; the uncertainty in the values is always explicitly stated.

For each of the ten binary alloy systems except three (aluminum-copper, aluminum-magnesium, and copper-zinc), the recommended (or provisional) values are given for 27 compositions: 0(pure element), 0.5, 1, 3, 5, 10(5)95, 97, 99, 99.5, and 100%(pure element). The alloy compositions in atomic percent corresponding to these in weight percent are also specified. For aluminum-copper alloy system, recommended values are presented for 26 compositions,

without that containing 80% copper. For aluminum-magnesium alloy system, recommended values are generated only for 12 compositions, lacking those containing 15 to 85% magnesium. Recommended values are given for only 11 compositions of the copper-zinc alloy system, and no values are for those with 35 to 99.5% zinc. For most of the compositions the recommended values cover the temperature range from 1 K to near the solidus temperature (melting starting point). The recommended values have been smoothed simultaneously over both temperature and composition dependences.

The recommended values for the elements are for well-annealed high-purity specimens of the respective elements; however, those values for temperatures below about 100 K are applicable only to the particular specimens having residual electrical resistivities as given at 1 K in the tables. The recommended values generated for the alloys are for those which are not ordered and have not been severely cold-worked or quenched; the electrical resistivity values would be lower for ordered alloys and higher for cold-worked alloys at low temperatures. Furthermore, the values generated are based on the room-temperature dimensions of the alloys, as thermal expansion corrections have not been made. This is due to the fact that the available experimental data on the electrical resistivity of the alloys, upon which the recommendations are based, are not corrected for thermal expansion, and that thermal expansion values for the respective alloys are not available for such corrections to be made. If the values of thermal expansion, $\Delta L(T)/L_0$, for the alloys are available, the electrical resistivity values corrected for thermal expansion, $\rho_{corrected}$, can easily be calculated from the given values uncorrected for thermal expansion, $\rho_{uncorrected}$, by the following relation:

$$\rho_{corrected}(T) = \left[1 + \frac{\Delta L(T)}{L_0}\right] \rho_{uncorrected}(T), \tag{29}$$

where $\Delta L = L - L_0$, and L and L_0 are the lengths of the specimen at any temperature T and at a reference temperature T_0, respectively. The thermal expansion correction amounts roughly to about -0.2% to -0.7% at very low temperatures, zero at room temperature, about 0.3% to 0.7% at 500 K, and about 2% near the melting point of the alloy.

In the figures presenting recommended (or provisional) electrical resistivity values as a function of temperature, continuous (solid) curves represent recommended values and long-dashed curves represent provisional values. The short-dashed

portion of any of the above two types of curves represents values in that temperature range where no experimental data are available. In a particular temperature range experimental data are considered to be available for a particular alloy composition for which recommended values have been generated if the available experimental data are for a composition closer to that particular composition than to the next composition for which recommended values have also been generated. If the available experimental data are for a composition in the middle of two compositions for which recommended values have been generated, experimental data are considered available for both compositions.

In the figures presenting experimental data, a data set consisting of a single data point is denoted by a number enclosed by a square, and a curve that connects a set of two or more data points is denoted by a ringed number. These data set numbers correspond to those listed in the accompanying tables providing measurement information and tabulating numerical data for each of the data sets. When several sets of data are too close together to be distinguishable, some of the data sets, though listed and tabulated in the tables, are omitted from the figure for the sake of clarity. The data set numbers of those data sets omitted from the figure are asterisked in both tables providing the measurement information and tabulating the experimental data. If only part of the data points of a data set are omitted from the figure, only those data points omitted are asterisked in the table tabulating the experimental data.

The tables providing the measurement information contain for each set of experimental data the following information: data set number, reference number, author(s), year of publication, experimental method used for the measurement, temperature range covered by the data, alloy name and specimen designation, alloy composition, specimen specification and characterization, and information on measurement conditions, which are contained in the original paper. The experimental methods used for the measurement of the electrical resistivity of alloys are indicated in the tables by the following code letters:

A Direct-current potentiometer method

B Direct-current bridge method

C Alternating-current potentiometer method

E Eddy current decay method

P Van der Pauw method

R Rotating magnetic field method

V Voltmeter and ammeter direct reading method

Details of these and other methods for the measurement of electrical resistivity may be found in the literature references given in Appendix 5.2, which presents a complete scheme for the classification and organization of the methods.

The last column of the table on measurement information with heading "Composition, Specification, and Remarks" should contain the following information on the specimen and its measurement if such information is provided in the original source document:

(1) Chemical composition,
(2) Type of crystal and crystalline axis orientation,
(3) Microstructure and inhomogeneity,
(4) Specimen shape and dimensions,
(5) Method and procedure of fabrication,
(6) Manufacturer, supplier, and stock number,
(7) Prior heat history and cold-work history,
(8) Heat treatment, cold working, irradiative and other treatments,
(9) Test environment such as measured in vacuum, or in nitrogen under pressure,
(10) Relevant physical properties such as density, transition temperature, Curie temperature, etc., and
(11) Whether the data were corrected for the thermal expansion of the specimen.

It will be noted, however, that in the majority of cases the authors did not report in their research papers all the necessary pertinent information.

In the tables tabulating the experimental data, all the original data reported in different units have been converted to have the same units: the SI units $10^{-8}\,\Omega\,m$. The recommended values generated are also given in the same units. Conversion factors for the units of electrical resistivity, which may be used to convert the electrical resistivity values in the SI units given in this work to values in other units, are given in Appendix 5.3.

It should be noted that in this work the measurement information and experimental data are given in the above two kinds of tables only for the

binary alloys, but not for the pure metals, even though the recommended values for the pure metals are given in the tables of recommended values. The experimental data and measurement information on the nine metallic elements which constitute the ten binary alloy systems together with details of their critical reviews, evaluations, and discussions are presented elsewhere [50-54].

In the figures presenting both recommended values and experimental data as a function of composition, for the sake of clarity recommended or provisional values are presented only for a selected few temperatures and are all represented as continuous (solid) curves. In these figures the alloy compositions are given in atomic percent, with weight percent indicated at the top of the figures.

3. ELECTRICAL RESISTIVITY OF BINARY ALLOY SYSTEMS

3.1. Aluminum-Copper Alloy System

The aluminum-copper alloy system does not form a continuous series of solid solutions. The maximum solid solubility of copper in aluminum is 5.7% (2.50 at.%) at 821 K and the solubility decreases to 0.1-0.2% (0.04-0.08 at.%) at 523 K. The maximum solid solubility of aluminum in copper is 9.4% (19.6 at.%) in the range from about 650 to 838 K and the solubility decreases at higher and lower temperatures. Thus the region of solid solution is limited.

There are 154 sets of experimental electrical resistivity data available for this system. Eight of the 27 data sets for Al + Cu alloys listed in table 2, tabulated in table 3, and shown in figure 3 are merely single data points. Most of the data were measured between 250 K and 700 K for alloys containing no more than 15% Cu. Only one single point is available at 4.2 K. Of the 106 data sets for Cu + Al alloys listed in table 4, tabulated in table 5, and shown in figure 4, 36 sets are single data points measured at 4.2 K or at room temperature. Most of the data were measured between room temperature and 1000 K. Three of the 21 resistivity - composition data sets listed in table 6, tabulated in table 7, and shown in figure 5 are for specimens in liquid state.

For the Al + Cu alloys, the resistivity - composition curve at 273 K was first determined in figure 5 following mainly the data of Smith [55] (Al-Cu data set 4). For ordinary alloys, it is usually reasonable to assume that the deviation of the electrical resistivity from the Matthiessen's rule due to alloying is small at low temperatures, say, below 50 K. The resistivity - composition curve at 4.2 K is then drawn parallel to the curve for 273 K. Starting from the values at these two temperatures, the recommended curves for the Al + Cu alloys were drawn according to the temperature dependence of the data of Griffiths and Schofield [56] (Al + Cu data sets 1-5).

For the Cu + Al alloys containing 10% Al or less, the recommended values for the resistivity at 293 K were obtained by drawing a best smooth isotherm so as to agree to within ±4% with the data of Gaudig and Warlimont [57] (Cu + Al data sets 86, 87), Panin et al. [58,59] (Cu + Al data sets 88, 90, 92, 94), Hibbard [60] (Cu + Al data set 48), Wechsler and Kernohan [61] (Cu + Al data set 43), Gulyaev and Trusova [62] (Al-Cu data set 16), Linde [63] (Cu + Al

data sets 44-46; Cu + Al data set 47 is 10% higher than the recommended value), and Smith and Palmer [64] (Cu + Al data sets 2, 3, 5, 6; Cu + Al data set 4 is 11% higher than the recommended values). For specimens containing more than 10% Al, the isotherm representing the recommended values for the resistivity at 293 K follows the trend of the room-temperature data of Pecijare and Jannsen [65,66] (Cu + Al data sets 33-42), Köster and Rothenbacher [67] (Cu + Al data sets 67-70), and Hishiyama [68] (Al-Cu data set 21). For these more concentrated alloys, it should be noted that some authors, notably Smith and Palmer [64] (Cu + Al data sets 8, 9), Sinha and Prasad [69] (Cu + Al data sets 52, 53), and Griffiths and Schofield [56] (Cu + Al data set 1), have reported resistivities as much as 30% greater than the recommended values. The isothermal resistivities suggested by these authors increase more rapidly as a function of increasing aluminum content than do the recommended values. The discrepancy is largely unexplained due to lack of information, other than to suggest a probable difference in specimen impurities and crystalline structures, which points to a need for detailed specimen characterization in any future work on the resistivity of these alloys. For specimens containing from 15 to 25% Al, the data indicate a maximum in the isothermal resistivity as a function of composition. However, there is insufficient evidence to indicate where the maximum is, and not enough information is available in this region to warrant the recommendation of values for the resistivity of the 20% Al alloy at 293 K or other temperatures.

The recommended values for the residual resistivities of Cu + Al alloys were generated by drawing a best smooth isotherm through the data of Weinberg [70] (Cu + Al data sets 65, 66), Chu and Lipschultz [71,72] (Cu + Al data sets 28, 55), Charlsey and Salter [73,74] (Cu + Al data sets 10-17, 19; Al-Cu data set 19), Kusonoki and Suzuki [75] (Cu + Al data set 20), Wechsler and Kernohan [61] (Cu + Al data set 43), Lindenfeld and Pennebaker [76] (Cu + Al data set 18), Kapoor et al. [77] (Cu + Al data sets 103-105), and Mitchell et al. [78] (Cu + Al data sets 22, 24). The great majority of those data lie within ±0.5 $10^{-8}\,\Omega\,m$ of the recommended isotherm. For alloys containing more than 10% Al, no measurements were made below 250 K except a single point for a 46% Al alloy at 4.2 K. Consequently no recommendations are made below 250 K for the more dense alloys. The recommended values for the resistivities at temperatures above room temperature were based primarily on the data of Smith and Palmer [64] (Cu + Al data

sets 2, 3, 5, 6), Gaudig and Warlimont [57] (Cu + Al data sets 86, 87), and Panin et al. [59] (Cu + Al data sets 92, 94) with some weight given to the data of Jannsen and Pecijare [65,66] (Cu + Al data sets 33-42) and Sinha and Prasad [69] (Cu + Al data sets 50-53).

The resulting recommended electrical resistivity values for Al, Cu, and for 24 Al-Cu binary alloys are presented in table 1 and shown in figures 1, 2, and 5. No values were generated for Cu + 20% Al alloy. The recommended values for Al and for Cu are for well-annealed high-purity specimens, but those values for temperatures below about 100 K are applicable only to Al and Cu having residual electrical resistivities as given at 1 K in table 1. The alloys for which the recommended values are generated are not ordered and have not been quenched or cold-worked severely. For most of the alloys, the recommended values cover a full range of temperature from 1 K to the solidus temperature of the alloy where melting starts. These values are not corrected for the thermal expansion of the material. The estimated uncertainties in the values for the various alloys and for different temperature ranges are explicitly stated in a footnote to table 1. Some of the values in table 1 are indicated as provisional because their uncertainties are greater than ±5%.

TABLE 1. RECOMMENDED ELECTRICAL RESISTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM†

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Al: 100.00% (100.00 At.%) Cu: 0.00% (0.00 At.%)		Al: 99.50% (99.79 At.%) Cu: 0.50% (0.21 At.%)		Al: 99.00% (99.57 At.%) Cu: 1.00% (0.43 At.%)		Al: 97.00% (98.70 At.%) Cu: 3.00% (1.30 At.%)		Al: 95.00% (97.81 At.%) Cu: 5.00% (2.19 At.%)		Al: 90.00% (95.49 At.%) Cu: 10.00% (4.51 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	0.00100*	1	0.043*	1	0.089*	1	0.269*	1	0.453*	1	0.934*
4	0.00100	4	0.043*	4	0.089	4	0.269*	4	0.453*	4	0.934*
7	0.00100	7	0.043*	7	0.089*	7	0.269*	7	0.453*	7	0.934*
10	0.00103	10	0.043*	10	0.089*	10	0.269*	10	0.453*	10	0.934*
15	0.00117	15	0.043*	15	0.089	15	0.269*	15	0.453*	15	0.934*
20	0.00168	20	0.044*	20	0.090	20	0.270*	20	0.454*	20	0.935*
25	0.00296	25	0.046*	25	0.092	25	0.273*	25	0.456*	25	0.936*
30	0.00564	30	0.050*	30	0.095	30	0.276*	30	0.459*	30	0.940*
40	0.0188	40	0.063*	40	0.109	40	0.289*	40	0.473*	40	0.954*
50	0.0480	50	0.092*	50	0.138	50	0.318*	50	0.502*	50	0.983*
60	0.0960	60	0.139*	60	0.186	60	0.366*	60	0.550*	60	1.03*
70	0.163	70	0.206*	70	0.252*	70	0.432	70	0.616	70	1.10*
80	0.246	80	0.289*	80	0.335*	80	0.515	80	0.699	80	1.18*
90	0.340	90	0.383*	90	0.429*	90	0.609	90	0.793	90	1.27
100	0.443	100	0.485*	100	0.531*	100	0.711	100	0.895	100	1.36
150	1.010	150	1.05*	150	1.10*	150	1.28	150	1.46	150	1.94
200	1.593	200	1.63*	200	1.68*	200	1.86	200	2.04	200	2.51
250	2.167	250	2.21*	250	2.25*	250	2.44	250	2.62	250	3.09
273	2.429	273	2.48	273	2.51	273	2.70	273	2.88	273	3.36
293	2.653	293	2.69	293	2.74	293	2.92	293	3.10	293	3.59
300	2.731	300	2.72	300	2.82	300	3.00	300	3.18	300	3.67
350	3.292	350	2.43*	350	3.38*	350	3.56	350	3.75	350	4.25
400	3.854	400	3.24*	400	3.95*	400	4.14	400	4.33	400	4.86
500	4.992	500	5.15*	500	5.10*	500	5.32	500	5.54	500	6.14
600	6.155	600	6.32*	600	6.28*	600	6.55	600	6.81	600	7.48
700	7.353	700	7.41	700	7.50	700	7.82	700	8.12	700	8.89
800	8.622	800	8.72	800	8.79	800	9.12	800	9.46	800	10.4
900	10.019	900	10.1	900	10.2	875	10.1	835	9.73	821	10.7
933.52	10.516*	923	10.4	913	10.3						

† Uncertainties in the electrical resistivity values are as follows:

100.00 Al - 0.00 Cu: ±2% below 80 K, ±1% from 80 to 200 K, ±0.5% above 200 K to 500 K, and ±2% above 500 K.
99.50 Al - 0.50 Cu: ±5% below 200 K, ±2% from 200 to 600 K, and ±3% above 600 K.
99.00 Al - 1.00 Cu: ±5% below 200 K, ±2% from 200 to 600 K, and ±3% above 600 K.
97.00 Al - 3.00 Cu: ±5% below 200 K, ±2% from 200 to 600 K, and ±3% above 600 K.
95.00 Al - 5.00 Cu: ±5% below 200 K, ±2% from 200 to 600 K, and ±5% above 600 K.
90.00 Al - 10.00 Cu: ±5% below 200 K, ±3% from 200 to 600 K, and ±5% above 600 K.

* In temperature range where no experimental data are available.

TABLE 1. RECOMMENDED ELECTRICAL RESISTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Al: 85.00% (93.03 At.%) Cu: 15.00% (6.97 At.%)		Al: 80.00% (90.40 At.%) Cu: 20.00% (9.60 At.%)		Al: 75.00% (87.60 At.%) Cu: 25.00% (12.40 At.%)		Al: 70.00% (84.60 At.%) Cu: 30.00% (15.40 At.%)		Al: 65.00% (81.39 At.%) Cu: 35.00% (18.61 At.%)		Al: 60.00% (77.94 At.%) Cu: 40.00% (22.06 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	1.44*	1	1.90*	1	2.28*	1	2.59*	1	2.82*	1	3.08*
4	1.44*	4	1.90*	4	2.28*	4	2.59*	4	2.82*	4	3.08*
7	1.44*	7	1.90*	7	2.28*	7	2.59*	7	2.82*	7	3.08*
10	1.44*	10	1.90*	10	2.28*	10	2.59*	10	2.82*	10	3.08*
15	1.44*	15	1.90*	15	2.28*	15	2.59*	15	2.82*	15	3.08*
20	1.44*	20	1.90*	20	2.28*	20	2.59*	20	2.82*	20	3.08*
25	1.44*	25	1.90*	25	2.28*	25	2.59*	25	2.82*	25	3.08*
30	1.45*	30	1.91*	30	2.29*	30	2.60*	30	2.83*	30	3.09*
40	1.46*	40	1.92*	40	2.30*	40	2.61*	40	2.84*	40	3.10*
50	1.49*	50	1.95*	50	2.33*	50	2.64*	50	2.87*	50	3.13*
60	1.54*	60	2.00*	60	2.38*	60	2.69*	60	2.92*	60	3.18*
70	1.60*	70	2.06*	70	2.45*	70	2.75*	70	2.99*	70	3.23*
80	1.69*	80	2.15*	80	2.53*	80	2.83*	80	3.06*	80	3.30*
90	1.78	90	2.24*	90	2.62*	90	2.92*	90	3.15*	90	3.39*
100	1.88	100	2.34*	100	2.72*	100	3.02*	100	3.25*	100	3.49*
150	2.45	150	2.91*	150	3.29*	150	3.56*	150	3.80*	150	4.01*
200	3.03	200	3.49*	200	3.87*	200	4.15*	200	4.39*	200	4.49*
250	3.61	250	4.06*	250	4.45*	250	4.74*	250	5.00*	250	5.14*
273	3.87	273	4.33*	273	4.72*	273	5.03*	273	5.31*	273	5.56*
293	4.10	293	4.58	293	4.98	293	5.31	293	5.61	293	5.88
300	4.19	300	4.67	300	5.07	300	5.41	300	5.71	300	5.99
350	4.79	350	5.31*	350	5.76*	350	6.16*	350	6.48*	350	6.77*
400	5.42	400	5.99*	400	6.49*	400	6.94*	400	7.30*	400	7.63*
500	6.76	500	7.42*	500	8.05*	500	8.62*	500	9.04*	500	9.49*
600	8.19	600	8.95*	600	9.68*	600	10.4*	600	10.9*	600	11.5*
700	9.69	700	10.6	700	11.4	700	12.2	700	12.8	700	13.5‡
800	11.3	800	12.3	800	13.3	800	14.2	800	15.0	800	15.8‡
821	11.7	821	12.7	821	13.6	821	14.6	821	15.4	821	16.2‡

† Uncertainties in the electrical resistivity values are as follows:

85.00 Al - 15.00 Cu: ±5% below 200 K, ±3% from 200 to 600 K, and ±5% above 600 K.
80.00 Al - 20.00 Cu: ±5% below 200 K, ±3% from 200 to 600 K, and ±5% above 600 K.
75.00 Al - 25.00 Cu: ±5% below 200 K, ±3% from 200 to 600 K, and ±5% above 600 K.
70.00 Al - 30.00 Cu: ±5% below 200 K, ±3% from 200 to 600 K, and ±5% above 600 K.
65.00 Al - 35.00 Cu: ±5% below 200 K, ±3% from 200 to 600 K, and ±5% above 600 K.
60.00 Al - 40.00 Cu: ±5% below 200 K, ±3% from 200 to 600 K, and ±6% above 600 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 1. RECOMMENDED ELECTRICAL RESISTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Al: 55.00% (74.22 At.%) Cu: 45.00% (25.78 At.%)		Al: 50.00% (70.20 At.%) Cu: 50.00% (29.80 At.%)		Al: 45.00% (65.83 At.%) Cu: 55.00% (34.17 At.%)		Al: 40.00% (61.09 At.%) Cu: 60.00% (38.91 At.%)		Al: 35.00% (55.91 At.%) Cu: 65.00% (44.09 At.%)		Al: 30.00% (50.23 At.%) Cu: 70.00% (49.77 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	3.33*‡	1	3.64*‡								
4	3.33*‡	4	3.64*‡								
7	3.33*‡	7	3.64*‡								
10	3.33*‡	10	3.64*‡								
15	3.33*‡	15	3.64*‡								
20	3.33*‡	20	3.64*‡								
25	3.33*‡	25	3.64*‡								
30	3.34*‡	30	3.65*‡								
40	3.35*‡	40	3.66*‡								
50	3.38*‡	50	3.69*‡								
60	3.43*‡	60	3.74*‡								
70	3.48*‡	70	3.79*‡								
80	3.54*‡	80	3.85*‡								
90	3.64*‡	90	3.92*‡								
100	3.77*‡	100	4.00*‡								
150	4.27*‡	150	4.52*‡								
200	4.85*	200	5.15*								
250	5.51*	250	5.86*	250	6.39*	250	7.14*	250	8.27*	250	10.5*
273	5.84*	273	6.22*	273	6.76*	273	7.57*	273	8.75*	273	11.2*
293	6.16	293	6.55	293	7.14	293	7.96	293	9.19	293	11.8
300	6.28	300	6.67	300	7.26	300	8.10	300	9.36	300	12.0
350	7.11*	350	7.55	350	8.21	350	9.12*	350	10.6*	350	13.5*
400	8.00*	400	8.52	400	9.23	400	10.2*	400	11.9*	400	15.2*
500	9.98*	500	10.6	500	11.5	500	12.7*	500	14.7*	500	18.7*
600	12.1*	600	12.8	600	13.8	600	15.3*	600	17.6*	600	22.5*
700	14.2‡	700	15.2‡	700	16.3‡	700	18.0*‡	700	20.7*‡	700	26.5*‡
800	16.5‡	800	17.6‡	800	18.9‡	800	20.9*‡	800	24.0*‡	800	30.8*‡
821	17.0‡	821	18.6‡	864	20.6*‡	864	22.8*‡	864	26.0*‡	864	33.6*‡

† Uncertainties in the electrical resistivity values are as follows:

55.00 Al - 45.00 Cu: ±7% below 200 K, ±3% from 200 to 600 K, and ±6% above 600 K.
50.00 Al - 50.00 Cu: ±10% below 200 K, ±3% from 200 to 600 K, and ±8% above 600 K.
45.00 Al - 55.00 Cu: ±3% up to 600 K and ±8% above 600 K.
40.00 Al - 60.00 Cu: ±5% up to 600 K and ±10% above 600 K.
35.00 Al - 65.00 Cu: ±5% up to 600 K and ±10% above 600 K.
30.00 Al - 70.00 Cu: ±5% up to 600 K and ±10% above 600 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 1. RECOMMENDED ELECTRICAL RESISTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Al: 25.00% (43.98 At.%) Cu: 75.00% (56.02 At.%)		Al: 15.00% (29.36 At.%) Cu: 85.00% (70.64 At.%)		Al: 10.00% (20.77 At.%) Cu: 90.00% (79.23 At.%)		Al: 5.00% (11.03 At.%) Cu: 95.00% (88.97 At.%)		Al: 3.00% (6.79 At.%) Cu: 97.00% (93.21 At.%)		Al: 1.00% (2.32 At.%) Cu: 99.00% (97.68 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
				1	8.10*‡	1	7.32‡	1	6.30*	1	2.92*
				4	8.10‡	4	7.32‡	4	6.30	4	2.92*
				7	8.10*‡	7	7.32‡	7	6.30*	7	2.92*
				10	8.10*‡	10	7.32‡	10	6.30*	10	2.92*
				15	8.11*‡	15	7.34‡	15	6.30*	15	2.92*
				20	8.12*‡	20	7.36‡	20	6.30	20	2.92*
				25	8.15*‡	25	7.39‡	25	6.31	25	2.93*
				30	8.18*‡	30	7.42‡	30	6.33	30	2.94*
				40	8.22*‡	40	7.49‡	40	6.37	40	2.97*
				50	8.29*‡	50	7.55‡	50	6.42	50	3.00*
				60	8.36*‡	60	7.61‡	60	6.48	60	3.04*
				70	8.41*‡	70	7.69‡	70	6.50	70	3.08*
				80	8.52*‡	80	7.78‡	80	6.58	80	3.13*
				90	8.61*‡	90	7.83‡	90	6.62	90	3.17*
				100	8.71*‡	100	7.92‡	100	6.68	100	3.22*
				150	9.29*‡	150	8.36‡	150	6.92	150	3.52*
				200	9.89*‡	200	8.79‡	200	7.27	200	3.89*
250	15.3*‡			250	10.5*‡	250	9.22‡	250	7.68	250	4.29
273	16.3*‡			273	10.8*‡	273	9.43‡	273	7.87	273	4.46*
293	17.2‡	293	12.3‡	293	11.0‡	293	9.61‡	293	8.01	293	4.60
300	17.6‡			300	11.1‡	300	9.68‡	300	8.10	300	4.65
350	19.9*‡			350	11.7‡	350	10.2‡	350	8.59	350	5.00
400	22.2*‡			400	12.3‡	400	10.7‡	400	9.10	400	5.37
500	27.2*‡			500	13.4‡	500	11.7‡	500	10.1	500	6.11*
600	32.6*‡			600	14.6‡	600	12.7‡	600	11.0	600	6.89*
700	38.4*‡			700	15.8‡	700	13.7‡	700	12.0	700	7.75*
800	44.6*‡			800	16.9‡	800	14.8‡	800	13.0*	800	8.67*
900	51.1*‡			900	18.1*‡	900	15.9*‡	900	14.1*	900	9.65*
939	53.8*‡			1000	19.3*‡	1000	17.0*‡	1000	15.2*	1000	10.7*
				1100	20.5*‡	1100	18.2*‡	1100	16.3*	1100	11.7*
				1200	21.6*‡	1200	19.3*‡	1200	17.5*	1200	12.7*
				1300	22.9*‡	1300	20.5*‡	1300	18.7*	1300	13.8*
				1313	23.0*‡	1331	20.8*‡	1343	19.1*	1353	14.3*

† Uncertainties in the electrical resistivity values are as follows:

25.00 Al - 75.00 Cu: ±8% up to 600 K and ±15% above 600 K.
15.00 Al - 85.00 Cu: ±12%.
10.00 Al - 90.00 Cu: ±12% up to 150 K and ±10% above 150 K.
5.00 Al - 95.00 Cu: ±7%.
3.00 Al - 97.00 Cu: ±5% below 200 K, ±3% from 200 to 800 K, and ±5% above 800 K.
1.00 Al - 99.00 Cu: ±5% below 200 K, ±3% from 200 to 800 K, and ±5% above 800 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 1. RECOMMENDED ELECTRICAL RESISTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM † (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Al: 0.50% (1.17 At.%) Cu: 99.50% (98.83 At.%)		Al: 0.00% (0.00 At.%) Cu: 100.00% (100.00 At.%)					
T	ρ	T	ρ				
1	1.49	1	0.00200				
4	1.49	4	0.00200				
7	1.49	7	0.00200				
10	1.49	10	0.00202				
15	1.49	15	0.00218				
20	1.49	20	0.00260				
25	1.49	25	0.00450				
30	1.50	30	0.00830				
40	1.51	40	0.0240				
50	1.54	50	0.0520				
60	1.58	60	0.0974				
70	1.62	70	0.154				
80	1.67	80	0.216				
90	1.72	90	0.282				
100	1.77	100	0.349				
150	2.12	150	0.701				
200	2.49	200	1.048				
250	2.87	250	1.388				
273	3.04	273	1.544				
293	3.17	293	1.678				
300	3.21	300	1.725				
350	3.56	350	2.061				
400	3.90	400	2.398				
500	4.62	500	3.079				
600	5.37	600	3.771				
700	6.18	700	4.481				
800	7.02*	800	5.213				
900	7.90*	900	5.973				
1000	8.79*	1000	6.766				
1100	9.71*	1100	7.596				
1200	10.7*	1200	8.470				
1300	11.7*	1300	9.395				
1354	11.6*	1357.6	9.946 (s)				
		1358	21.01 (ℓ)				
		1700	24.41				

† Uncertainties in the electrical resistivity values are as follows:

0.50 Al – 99.50 Cu: ±5% below 200 K, ±3% from 200 to 800 K, and ±5% above 800 K.
0.00 Al – 100.00 Cu: ±3% up to 100 K, ±1% above 100 K to 250 K, ±0.5% above 250 K to 350 K, ±1% above 350 K to 500 K, ±4% above 500 K to 1357.6 K, and ±5% above 1357.6 K.

* In temperature range where no experimental data are available.

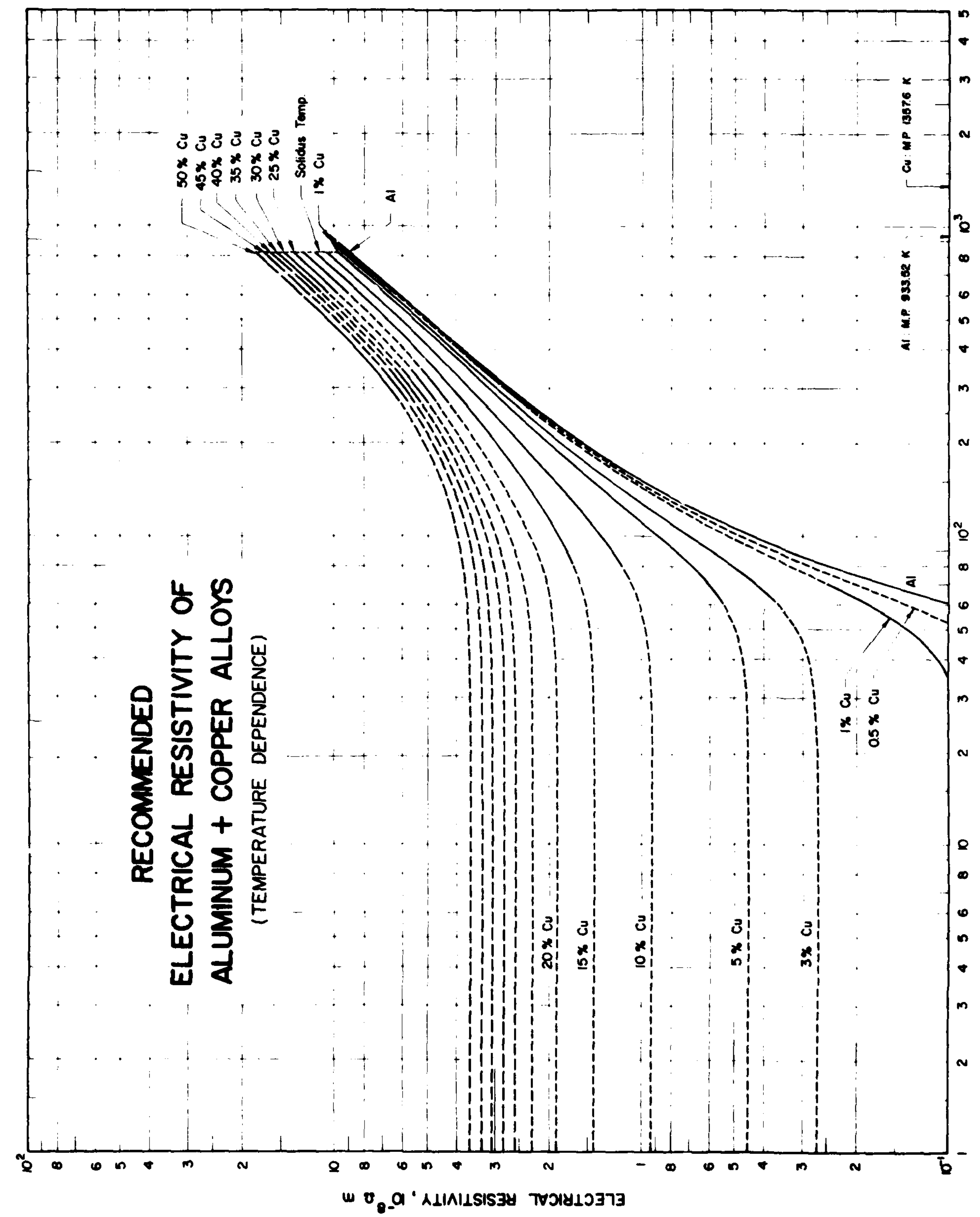
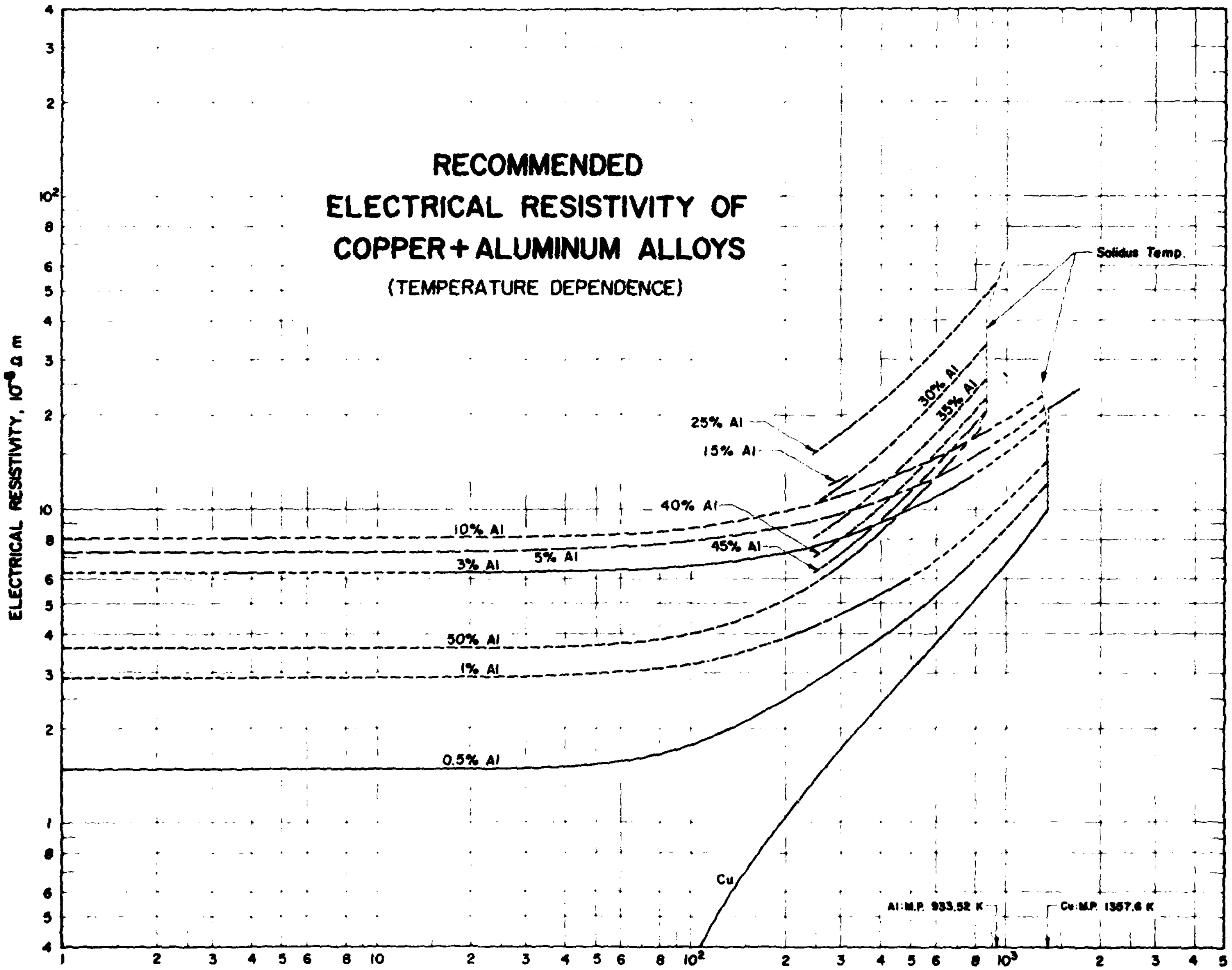

RECOMMENDED
ELECTRICAL RESISTIVITY OF
ALUMINUM + COPPER ALLOYS
(TEMPERATURE DEPENDENCE)
50 % Cu
45 % Cu
40 % Cu
35 % Cu
30 % Cu
25 % Cu
Solidus Temp.
1% Cu
Al
20 % Cu
15 % Cu
10 % Cu
5 % Cu
3% Cu
1% Cu
0.5 % Cu
Al: M.P. 933.52 K
Cu: M.P. 1357.6 K
TEMPERATURE , K
ELECTRICAL RESISTIVITY, $10^{-8}\ \Omega$ m
CINDAS

FIGURE 1



CINDAS

FIGURE 2

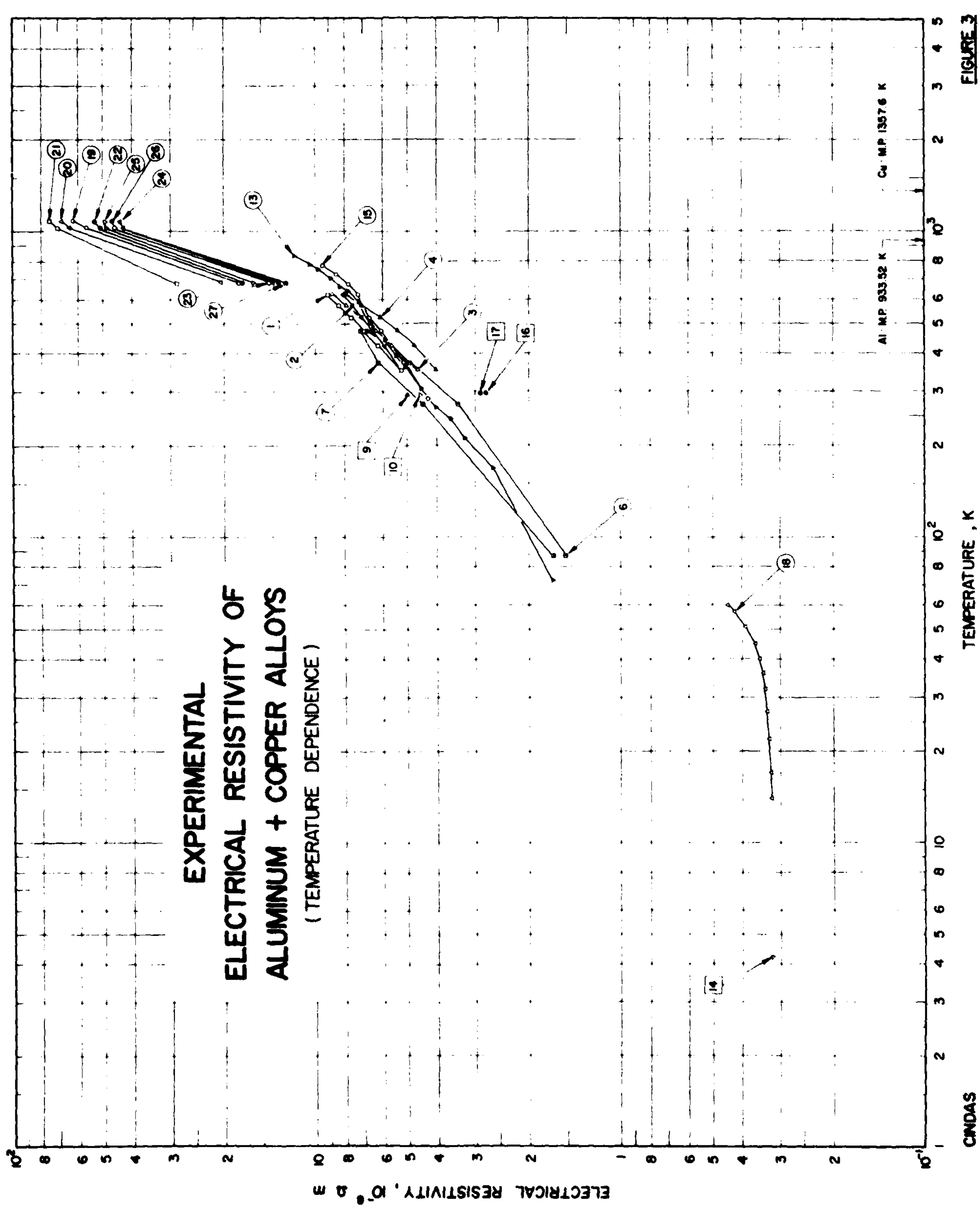
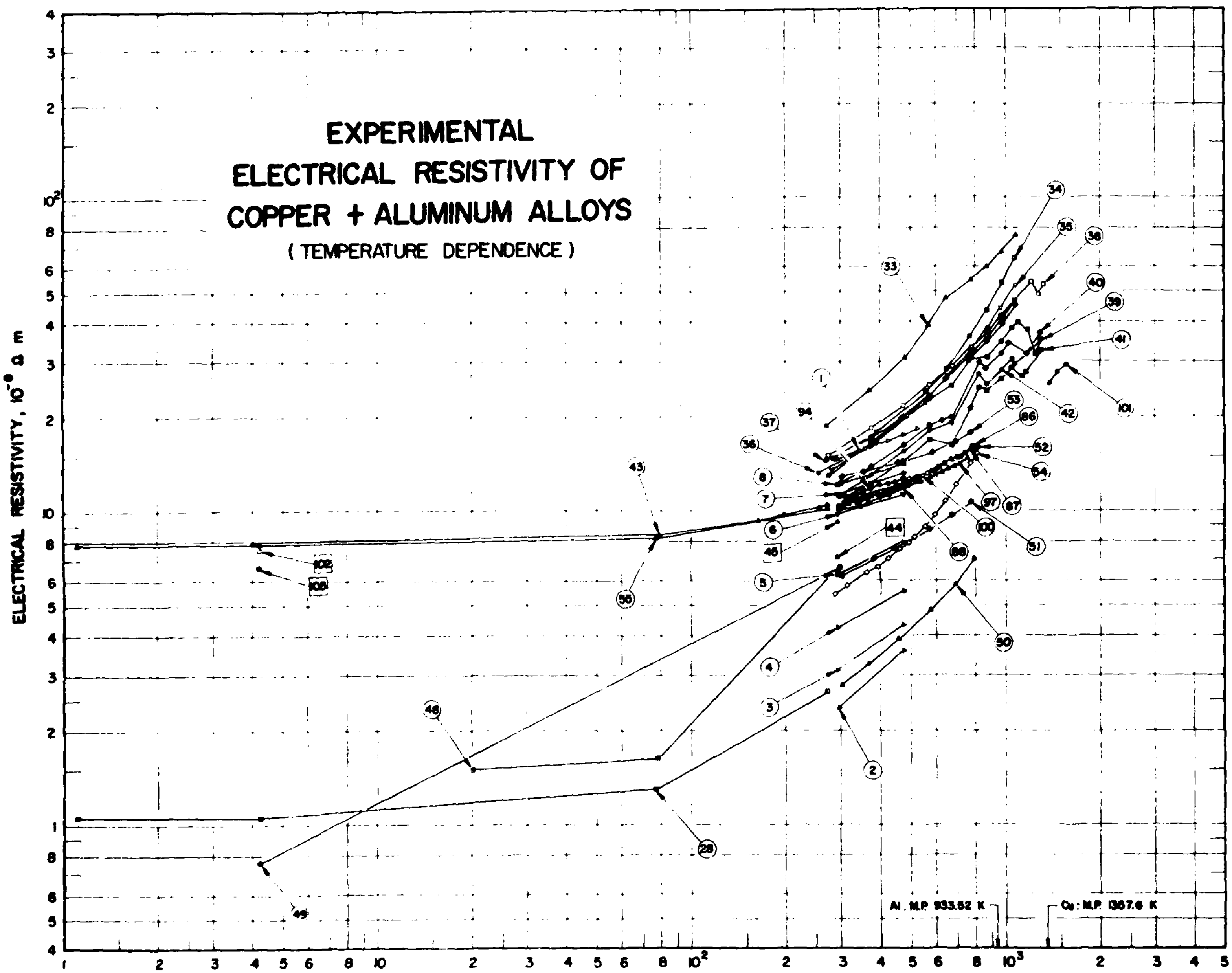

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
ALUMINUM + COPPER ALLOYS
(TEMPERATURE DEPENDENCE)
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE , K
Al M.P. 933.52 K
Cu M.P. 1357.6 K
CINDAS

FIGURE 3



CINDAS

FIGURE 4

TABLE 2. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF ALUMINUM + COPPER ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Al	Cu	Composition (continued), Specifications, and Remarks
1	56	Griffiths, E. and Schofield, F.H.	1928	A	353-623	No. 655	86.0	14.0	Cast and annealed at 450 C for 1 hr.
2	56	Griffiths, E. and Schofield, F.H.	1928	A	353-623	No. 671	88.0	12.0	Similar to the above specimen.
3	56	Griffiths, E. and Schofield, F.H.	1928	A	353-623	No. 921	~88.0	~12.0	Similar to the above specimen.
4	56	Griffiths, E. and Schofield, F.H.	1928	A	353-623	No. 2313	92.0	8.0	Similar to the above specimen.
5*	56	Griffiths, E. and Schofield, F.H.	1928	A	353-623	No. 2312	95.5	4.5	Similar to the above specimen.
6	79	Mannchen, W.	1931	V	87-476		92.0	8.0	Cast.
7	79	Mannchen, W.	1931	V	87-476		[illegible]	15.0	Cast.
8*	80	Grard, C. and Villey, J.	1927		373.2		88.0	12.0	Cast.
9	81	Elflein, M.	1937	B	293.2	I, 1	95	5	Cast from 98 to 99 pure Al bar (contamination: <1.0 Fe, <0.9 Si, and <0.1 Cu + Zn) and key alloy (50 Al and 50 Cu) at 750 C, and then cooled in air.
10	81	Elflein, M.	1937	B	293.2	I, 5	95	5	Similar to the above specimen except 99.5 pure Al notch bar (contamination: 0.28 Fe and 0.22 Si) used for the alloying.
11*	81	Elflein, M.	1937	B	293.2	I, 5A	95	5	Similar to the above specimen.
12*	81	Elflein, M.	1937	B	293.2	I, 5B	95	5	Similar to the above specimen.
13	82	Turnbull, D., Rosenbaum, H.S., and Treaftis, H.N.	1960		72-839			3.9	Calculated composition (1.7 a/o Cu); 3 x 0.2 x 0.010 cm; prepared by cold swaging, drawing, and rolling; homogenized at 550 C and quenched to 223 K.
14	83	Caplin, A.D. and Rizzuto, C.	1971	A	4.2			1.01	Calculated composition (0.43 a/o Cu); 1.50 mm in diameter; prepared by quenching from the melt, drawing, annealing for several hr just below 660 C, and quenching in water.
15	84	Bollenrath, F. and Hank, V.	1948		285-775			5.08	0.15 Fe, 0.05 each of Si and Zn, 0.02 Ti, and traces Mg and Mn; cast; heated at 794 K for 6 hr and water quenched.
16	85	Robinson, A.T. and Dorn, J.E.	1951	B	297.2			0.238	Calculated composition (0.101 a/o Cu); impurities: 0.003 Fe, 0.003 Si, 0.001 Mn, and 0.0006 Mg; sheet specimen 0.070 in. thick and 0.250 in. wide.
17	85	Robinson, A.T. and Dorn, J.E.	1951	B	297.2			0.547	Calculated composition (0.233 a/o Cu); impurities: 0.004 Fe, 0.003 Si, 0.001 Mn, and 0.0006 Mg; sheet specimen 0.070 in. thick and 0.250 in. wide.
18	86	Caplin, A.D. and Rizzuto, C.	1970	A	14-60			1.01	Calculated composition (0.43 a/o Cu); residual resistivity 0.320 $\mu\Omega$ cm.
19	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	673-1078			1.5	In solid and liquid states.

* Not shown in figure.

TABLE 2. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF ALUMINUM + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Al	Cu	Composition (continued), Specifications, and Remarks
20	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	673-1075			2.7	In solid and liquid states.
21	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	673-1066			5.5	In solid and liquid states.
22	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	673-1053			11.5	In solid and liquid states.
23	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	673, 1023			20.0	In solid and liquid states.
24	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	673-1023			26.8	In solid and liquid states.
25	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	673-1023			33.2	In solid and liquid states.
26	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	673-1023			37.9	In solid and liquid states.
27	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	673-1023			44.1	In solid and liquid states.

TABLE 3. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF ALUMINUM + COPPER ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega\ m$]

T	ρ
DATA SET 1	
353	5.24
423	6.25
473	6.97
523	7.69
573	8.40
623	9.14
DATA SET 2	
353	5.20*
423	5.96
473	6.51
523	7.03
573	7.57
623	8.11
DATA SET 3	
353	4.64
423	5.61
473	6.34
523	7.12*
573	7.95
623	8.82
DATA SET 4	
353	4.06
423	4.77
473	5.40
523	6.16
573	7.03
623	8.08
DATA SET 5*	
353	4.04
423	4.96
473	5.61
523	6.26
573	6.92
623	7.58
DATA SET 6	
87	1.536
273	3.413
DATA SET 6 (cont.)	
373	4.950
476	6.849
DATA SET 7	
87	1.678
273	4.484
373	6.250
476	7.042
DATA SET 8*	
373.2	6.25
DATA SET 9	
293.2	5.00
DATA SET 10	
293.2	4.56
DATA SET 11*	
293.2	4.66
DATA SET 12*	
293.2	4.42
DATA SET 13	
72	1.68
164	2.69
178	2.85*
211	3.25
245	3.62
266	4.04
283	4.23*
294	4.39*
309	4.50
361	5.10
381	5.30*
395	5.46
420	5.73*
444	5.95
456	6.17*
DATA SET 13 (cont.)	
479	6.38*
501	6.63
531	6.74*
549	6.74*
572	6.99*
591	7.23
619	7.58*
642	7.90
667	8.36
691	8.74*
709	8.96
731	9.37*
755	9.84
767	10.14*
784	10.37*
788	10.50
817	10.87*
829	11.02*
839	11.18
DATA SET 14	
4.2	0.320
DATA SET 15	
285	4.30
375	5.15
425	5.60*
475	6.10
525	6.65
575	7.00*
625	7.28
675	7.80
725	8.55
775	9.50
DATA SET 16	
297.2	2.793
DATA SET 17	
297.2	2.889
DATA SET 18	
14	0.321
17	0.322
22	0.327
27	0.331
32	0.336
36	0.341
40	0.352
45	0.364
51	0.394
57	0.429
60	0.448
DATA SET 19	
673	18.1
1023	57.6
1078	63.9
DATA SET 20	
673	20.8
1023	65.5
1075	69.7
DATA SET 21	
673	28.4
1023	71.8
1066	76.0
DATA SET 22	
673	17.5
1023	51.8
1053	54.2
DATA SET 23	
673	14.4
1023	46.3
DATA SET 24	
673	14.0
995	43.6
1023	44.6
DATA SET 25	
673	16.2
971	49.4
1023	50.0
DATA SET 26	
673	13.4
986	46.3
1023	47.3
DATA SET 27	
673	12.7
1002	47.8*
1023	48.3*

* Not shown in figure.

TABLE 4. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ALUMINUM ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
1	56	Griffiths, E. and Schofield, F.H.	1928	A	293-523	Aluminum bronze; 6	90.0	10.0	Chill-cast and annealed; $d\rho/dT = 0.00106\ \mu\Omega\ cm\ K^{-1}$ between 293 and 523 K.
2	64	Smith, C.S. and Palmer, E.W.	1935	B	293,473	100	99.77	0.22	0.01 Fe; rolled, annealed, and cold drawn; heat-treated at 750 C for 2 hr.
3	64	Smith, C.S. and Palmer, E.W.	1935	B	293,473	101	99.47	0.47	0.02 Fe; similar to the above specimen.
4	64	Smith, C.S. and Palmer, E.W.	1935	B	293,473	76	99.20	0.71	0.09 Fe; similar to the above specimen.
5	64	Smith, C.S. and Palmer, E.W.	1935	B	293,473	77	98.08	1.89	0.03 Fe; similar to the above specimen.
6	64	Smith, C.S. and Palmer, E.W.	1935	B	293,473	45	95.25	4.61	0.14 Fe; similar to the above specimen.
7	64	Smith, C.S. and Palmer, E.W.	1935	B	293,473	46	92.15	7.72	0.13 Fe; rolled, annealed, and cold drawn; heat-treated at 750 C for 3.5 hr, *slowly cooled in furnace*.
8	64	Smith, C.S. and Palmer, E.W.	1935	B	293,473	102	90.56	9.37	0.07 Fe; similar to the above specimen.
9*	64	Smith, C.S. and Palmer, E.W.	1935	B	293,473	130	87.76	12.15	0.09 Fe; similar to the above specimen.
10*	73	Salter, J.A.M. and Charsley, P.	1967	A	4.2	28	99.17	0.83	Calculated composition (1.93 a/o Al); single crystal; grown in a sealed graphite mold using the Bridgman technique.
11*	73	Salter, J.A.M. and Charsley, P.	1967	A	4.2	2	97.10	0.90	Calculated composition (2.09 a/o Al); polycrystalline; annealed at 750 C for 14 hr in vacuo; grain size 0.008 cm.
12*	73	Salter, J.A.M. and Charsley, P.	1967	A	4.2	2AR	99.17	0.83	Calculated composition (1.93 a/o Al); polycrystalline; grain size 0.0015 cm; 3 mm diameter x 12 cm long; prepared by International Research and Development Co.; cast, machined, swaged, and drawn; annealed at 750 C for 14 hr.
13*	73	Salter, J.A.M. and Charsley, P.	1967	A	4.2	8S	96.69	3.31	Calculated composition (7.45 a/o Al); single crystal; grown in a sealed graphite mold using the Bridgman technique.
14*	73	Salter, J.A.M. and Charsley, P.	1967	A	4.2	8	95.91	4.09	Calculated composition (9.12 a/o Al); polycrystalline; annealed in vacuo at 150 C for 14 hr; grain size 0.0063 cm.
15*	73	Salter, J.A.M. and Charsley, P.	1967	A	4.2	12	94.89	5.11	Calculated composition (11.25 a/o Al); similar to the above specimen.
16*	73	Salter, J.A.M. and Charsley, P.	1967	A	4.2	12(550)	94.72	5.28	Calculated composition (11.60 a/o Al); polycrystalline; grain size 0.0025 cm; 3 mm diameter x 12 cm long; prepared by International Research and Development Co.; cast, machined, swaged, and drawn; annealed in vacuo at 750 C for 14 hr.
17*	73	Salter, J.A.M. and Charsley, P.	1967	A	4.2	12(450)	94.72	5.28	Calculated composition (11.60 a/o Al); polycrystalline; annealed in vacuo at 450 C for 14 hr; grain size 0.0009 cm.
18*	76	Lindenfeld, P. and Pennebaker, W.C.	1962		4.2		99.383	0.617	Calculated composition; prepared from 99.999 pure Cu and 99.99+ pure Al; materials melted, outgassed in vacuum, stirred for 0.5 h, then cast; annealed at 700 C for 22 hr.

* Not shown in figure.

TABLE 4. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ALUMINUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
19*	74	Charsley, P. and Salter, J.A.M.	1965	A	4.2	12S	94.89	5.11	Calculated composition (11.25 a/o Al); single crystal grown by Bridgman technique.
20*	75	Kusunoki, M. and Suzuki, H.	1969		4.2	Specimen No. 5	93.03	6.97	Calculated composition (15 at.% Al); single crystal; 2.546 cm^2 in cross-section and about 40 mm long; prepared from 99.999 pure Cu (Mitsubishi-Kinzoku Co. Ltd.) and 99.99 pure Al (Sumitomo-Kinzoku Co. Ltd.) by melting in a high purity graphite crucible by induction heating; grown in a splitting graphite mold by the Bridgman method using a seed crystal; annealed at 1000 C for 48 hr in a vacuum lower than 10^{-5} mm Hg; electrolytically polished in phosphoric acid - ethyl alcohol; dislocation density 5.8×10^{10} cm^{-2}.
21*	78	Mitchell, M.A., Klemens, P.G., and Reynolds, C.A.	1971	A	4.2	A		4.5	Obtained from Materials Research Corp., Orangeburg, N.Y.; prepared from 99.999 pure Al and Cu by vacuum induction melting, then machining and swaging to 0.125 in. in diameter; cold-worked in liquid nitrogen, then kept at 293 K for 3 hr.
22*	78	Mitchell, M.A., et al.	1971	A	4.2	B		4.5	Similar to the above specimen A except annealed at 1193 K for 48 hr after cold-work.
23*	78	Mitchell, M.A., et al.	1971	A	4.2	C		4.5	Similar to the above specimen A except annealed at 1123 K for 28 hr after cold-work, then given 9.5% torsional strain at 293 K, reannealed for 12 hr to 48 hr consecutively at various temperatures.
24*	78	Mitchell, M.A., et al.	1971	A	4.2	D		4.5	Same composition, supplier, and fabrication method as the above specimen A except swaged to 3/16 in. in diameter; annealed at 1205 K for 48 hr.
25*	78	Mitchell, M.A., et al.	1971	A	4.2	E		4.5	Similar to the above specimen D except given, after annealing, 9.33% tensile strain at 77 K with maximum stress 28.5 kg mm^{-2} and strain rate 0.0093 s^{-1}, then reannealed for 12 hr to 48 hr consecutively at various temperatures.
26*	78	Mitchell, M.A., et al.	1971	A	4.2	F		4.5	Similar to the above specimen E except annealed at 1202 K for 48 hr, then given 8.13% tensile strain at 77 K with maximum stress 29 kg mm^{-2} and strain rate 0.0081 s^{-1}, reannealed for 0.5 to 97 hr consecutively at various temperatures.
27*	78	Mitchell, M.A., et al.	1971	A	4.2	G		4.5	Similar to the above specimen F except given, after annealing, 9.26% tensile strain at 77 K with maximum stress 25.1 kg mm^{-2} and strain rate 0.004 s^{-1}, reannealed for 0.5 to 48 hr consecutively at various temperatures.
28	71, 72	Chu, T.K. and Lipschultz, F.P.	1972	A	1.1-273	C1		0.43	Supplied by American Anaconda Brass Co.; 0.5 in. diameter x 8 in. long with central 5 in. machined to 0.25 in. in diameter; annealed at 1273 K for 48 hr.
29*	71, 72	Chu, T.K. and Lipschultz, F.P.	1972	A	1.1-273	C2			The above specimen fatigued for 500 cycles with maximum load 6.4 kg mm^{-2}.
30*	71, 72	Chu, T.K. and Lipschultz, F.P.	1972	A	1.1-273	C3			The above specimen fatigued for 10^4 cycles with maximum load 6.4 kg mm^{-2}.
31*	71, 72	Chu, T.K. and Lipschultz, F.P.	1972	A	1.1-273	C5			Similar to the above specimen C1 except given a 5% plastic deform under uniaxial stress.

* Not shown in figure.

TABLE 4. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ALUMINUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
32*	71, 72	Chu, T.K. and Lipschultz, F.P.	1972	A	4.2-273	C6			The above specimen fatigued for 10^5 cycles with maximum load 6.4 kg mm^{-2}.
33	65	Pecijare, O. and Janssen, S.	1957		270-1080			18.30	In γ_2 phase.
34	65	Pecijare, O. and Janssen, S.	1957		285-1075			19.30	Similar to the above specimen.
35	65	Pecijare, O. and Janssen, S.	1957		280-1080			17.05	Similar to the above specimen.
36	65	Pecijare, O. and Janssen, S.	1957		255-1082			17.40	Similar to the above specimen.
37	65	Pecijare, C. and Janssen, S.	1957		270-1072			16.41	Similar to the above specimen.
38	66	Janssen, S. and Pecijare, O.	1957		275-1315			16.4	No details reported.
39	66	Janssen, S. and Pecijare, O.	1957		275-1300			15.15	No details reported.
40	66	Janssen, S. and Pecijare, O.	1957		300-1295			14.9	No details reported.
41	66	Janssen, S. and Pecijare, O.	1957		318-1300			14.5	No details reported.
42	66	Janssen, S. and Pecijare, O.	1957		299-1290			13.9	No details reported.
43	61	Wechsler, M.S. and Kernohan, R.H.	1958	A	4.0-322			6.97	Calculated composition (15 a/o Al); polycrystalline; grain size 200 grains mm^{-2}; 0.125 in. in diameter; supplied by Metallurgical Division at ORNL; prepared from 99.92 pure electrolytic Cu and 99.97 pure Al; vacuum-cast, homogenized and swaged, annealed at about 1023 K for several hr, then cooled at 15 K h^{-1} to room temperature.
44	63	Linde, J.O.	1954	B	293.2			2.5	Calculated composition (5.6 a/o Al); prepared from Johnson, Matthey spectroscopically standardized metals; rolled, homogenized at 1173 K for about 10 hr, rolled to about 0.4 mm^2 in cross-section; annealed in vacuum at 723 to 773 K for 15 hr; density 8.51 g cm^{-3}.
45	63	Linde, J.O.	1954	B	293.2			4.5	Calculated composition (10.0 a/o Al); similar to the above specimen except density 8.23 g cm^{-3}.
46*	63	Linde, J.O.	1954	B	293.2			6.3	Calculated composition (13.6 a/o Al); similar to the above specimen except density 7.98 g cm^{-3}.
47*	63	Linde, J.O.	1954	B	293.2			8.6	Calculated composition (18.1 a/o Al); similar to the above specimen except density 7.68 g cm^{-3}.
48	60	Hibbard, W.R., Jr.	1950		20-299			1.81	Calculated composition (4.15 a/o Al); annealed at 470 C for 2 hr; grain size 0.0117 mm.
49	88	Galewek, J.J. and Wasik, C.A.	1971	A	4.2, 295		54	46	Polycrystalline; 49 cm wide and 0.048 cm thick.

* Not shown in figure.

TABLE 4. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ALUMINUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
50	69	Sinha, T.H.D. and Prasad, R.S.	1970	A	302-792	AC_1	99.57	0.43	Prepared by National Metallurgical Laboratory, Jamshedpur; residual electrical resistivity 0.5 μΩ cm.
51	69	Sinha, T.H.D. and Prasad, R.S.	1970	A	302-773	AC_2	98.44	1.56	Prepared by National Metallurgical Laboratory, Jamshedpur; residual electrical resistivity 3.5 μΩ cm.
52	69	Sinha, T.H.D. and Prasad, R.S.	1970	A	307-817	AC_3	94.4	5.6	Prepared by National Metallurgical Laboratory, Jamshedpur; residual electrical resistivity 7.5 μΩ cm.
53	69	Sinha, T.H.D. and Prasad, R.S.	1970	A	303-779	AC_4	91.4	8.6	Prepared by National Metallurgical Laboratory, Jamshedpur; residual electrical resistivity 9.7 μΩ cm.
54	69	Watanabe, K. and Katsui, A.	1968		288-807		54.3	45.7	3 mm diameter cylindrical specimen; prepared by melting together in an argon atmosphere 99.99 pure Al and Cu; annealed for 2 days at 500 C in vacuum and cooled at 50-60 C/h.
55	71, 72	Chu, T.K. and Lipschultz, F.P.	1972	A	1.1-273	B1		6.97	Same supplier and dimensions as the above specimen C1 for data set No. 28; annealed at 1273 K for 48 h.
56*	71, 72	Chu, T.K. and Lipschultz, F.P.	1972	A	1.1-273	B2			The above specimen fatigued for 500 cycles with maximum load 8.3 kg mm^{-2}.
57*	71, 72	Chu, T.K. and Lipschultz, F.P.	1972	A	1.1-273	B3			The above specimen fatigued for 10^4 cycles.
58*	71, 72	Chu, T.K. and Lipschultz, F.P.	1972	A	1.1-273	B4			The above specimen fatigued for 10^5 cycles.
59*	71, 72	Chu, T.K. and Lipschultz, F.P.	1972	A	1.1-273	B5		6.97	Similar to the above specimen B1 except given a 5% plastic deform under uniaxial stress.
60*	71, 72	Chu, T.K. and Lipschultz, F.P.	1972	A	4.2-273	B6			The above specimen fatigued for 2×10^5 cycles with maximum load 8.3 kg mm^{-2}.
61*	90	Leaver, A.D.W. and Charsley, P.	1971		4.2	2 Al		0.83	Polycrystalline; 3 mm diameter x 10 cm long; obtained from International Research and Development Co.; annealed at 750 C for 15 h.
62*	90	Leaver, A.D.W. and Charsley, P.	1971		4.2	2 Al			The above specimen tensile strained 8.2% under a stress of 16.93 kg mm^{-2}.
63*	90	Leaver, A.D.W. and Charsley, P.	1971		4.2	12 Al		5.56	Polycrystalline; obtained from International Research and Development Co.
64*	90	Leaver, A.D.W. and Charsley, P.	1971		4.2	12 Al			The above specimen tensile strained 1.8% under a stress of 16.38 kg mm^{-2}.
65*	70	Weinberg, I.	1965		4.2			0.33	Calculated composition (0.77 a/o Al).
66*	70	Weinberg, I.	1965		4.2			1.02	Calculated composition (2.37 a/o Al).
67*	67	Köster, W. and Rothenbacher, P.	1967		298.2		87.5	12.5	Recrystallized.
68*	67	Köster, W. and Rothenbacher, P.	1967		298.2		91.7	8.3	Recrystallized.
69*	67	Köster, W. and Rothenbacher, P.	1967		298.2		87.5	12.5	Recrystallized.

* Not shown in figure.

TABLE 4. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ALUMINUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
70*	67	Köster, W. and Rothenbacher, P.	1967		298.2		84	16	Recrystallized.
71*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			1.7	Calculated composition (4 a/o Al); prepared from 99.95 pure electrolytic copper and 99.9 pure aluminum; in liquid state.
72*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			4.5	Calculated composition (10 a/o Al); similar to the above specimen.
73*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			6.0	Calculated composition (13 a/o Al); similar to the above specimen.
74*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			8.5	Calculated composition (18 a/o Al); similar to the above specimen.
75*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			9.6	Calculated composition (20 a/o Al); similar to the above specimen.
76*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			10.7	Calculated composition (22 a/o Al); similar to the above specimen.
77*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			12.4	Calculated composition (25 a/o Al); similar to the above specimen.
78*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			13.6	Calculated composition (27 a/o Al); similar to the above specimen.
79*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			14.8	Calculated composition (29 a/o Al); similar to the above specimen.
80*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			17.9	Calculated composition (34 a/o Al); similar to the above specimen.
81*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			19.3	Calculated composition (36 a/o Al); similar to the above specimen.
82*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			23.5	Calculated composition (42 a/o Al); similar to the above specimen.
83*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			25.8	Calculated composition (45 a/o Al); similar to the above specimen.
84*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			29.8	Calculated composition (50 a/o Al); similar to the above specimen.
85*	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373, 1473			49.8	Calculated composition (70 a/o Al); similar to the above specimen.
86	57	Gaudig, W. and Warlimont, H.	1969	A	297-786			6.97	Calculated composition (15 a/o Al); wire specimen 0.9 mm in diameter; prepared from 99.999 pure copper and 99.99 pure aluminum; annealed in argon at 773 K and cooled slowly to room temperature.
87	57	Gaudig, W. and Warlimont, H.	1969	A	300-772				The above specimen measured at decreasing temperatures.

* Not shown in figure.

TABLE 4. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ALUMINUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Al	Composition (continued), Specifications, and Remarks
88	58	Panin, V. Ye., Zenkova, E.K., and Fadin, V.P.	1962		299-474			6.62	Calculated composition (14.3 a/o Al); 1 mm in diameter and 100 to 120 mm long; prepared from 99.99 pure Al and Cu; cast, forged, and rolled; heated at a rate of 6 C min^{-1} and annealed.
89*	58	Panin, V.Ye., et al.	1962		300-404				The above specimen quenched from 400 C.
90*	58	Panin, V.Ye., et al.	1962		298-369				Similar to the above specimen for dataset No. 88 except heated at a rate of 0.6 C min^{-1} and annealed.
91*	58	Panin, V.Ye., et al.	1962		334-388				The above specimen quenched from 400 C.
92*	59	Panin, V.Ye., Fadin, V.P., and Solov'yev, L.A.	1962		298-473			9.76	Calculated composition (20.3 a/o Al); prepared from 99.99 pure Al and Cu; vacuum cast; heated at a rate of 6 C min^{-1} and annealed.
93*	59	Panin, V.Ye., et al.	1962		299-413				The above specimen quenched from 500 C.
94	59	Panin, V.Ye., et al.	1962		299-472				Similar to the above specimen for data set No. 92 except heated at a rate of 0.6 C min^{-1} and annealed.
95*	59	Panin, V.Ye., et al.	1962		296-359				The above specimen quenched from 500 C.
96*	92	Sidorova, T.S., Panin, V.Ye., and Bol'shanina, M.A.	1962	B	311-586			6.62	Similar to the specimen for data set No. 88; annealed at 750 C for 2 h and cooled at a rate of 50 C h^{-1}; deformed 4% at room temperature by drawing; heated at a rate of 6 C min^{-1}.
97	92	Sidorova, T.S., et al.	1962	B	307-762				Similar to the above specimen except deformed 27%.
98*	92	Sidorova, T.S., et al.	1962	B	307-772				Similar to the above specimen except deformed 44%.
99*	92	Sidorova, T.S., et al.	1962	B	446-567				Similar to the above specimen for data set No. 96 except heated at a rate of 0.6 C min^{-1}.
100	92	Sidorova, T.S., et al.	1962	B	475-563				Similar to the above specimen except deformed 44%.
101	93	Scala, E. and Robertson, W.D.	1953	A	1381-1557			0.29	Calculated composition (0.95 a/o Al); impurities: <0.001 each of Fe, Mg, Si, and Sn; in liquid state; contained in a refractory insulating tube about 0.6 cm I.D. and 13 cm long.
102	77	Kapoor, A., Rowlands, J.A., and Woods, S.B.	1974	A	4.2			4.5	Calculated composition (10 a/o Al); 3.6 mm in diameter; prepared by melting pure metals in vacuum, then swaging to size; cold-worked.
103*	77	Kapoor, A., et al.	1974	A	4.2				The above specimen annealed in vacuum at 873 K for 12 h.
104*	77	Kapoor, A., et al.	1974	A	4.2				The above specimen reannealed in vacuum at 948 K for 12 h.
105	77	Kapoor, A., et al.	1974	A	4.2				The above specimen reannealed in vacuum at 1273 K for 12 h.
106*	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	673-1023		54.0	46.0	In solid and liquid states.

* Not shown in figure.

TABLE 5. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + ALUMINUM ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ωm]

T	ρ
DATA SET 1	
293	14.7
348	15.6
373	16.0
423	16.7
473	17.5
523	18.3
DATA SET 2	
293.2	2.386
473.2	3.625
DATA SET 3	
293.2	3.115
473.2	4.365
DATA SET 4	
293.2	4.274
473.2	5.571
DATA SET 5	
293.2	6.285
473.2	7.692
DATA SET 6	
293.2	9.747
473.2	11.333
DATA SET 7	
293.2	11.320
473.2	13.072
DATA SET 8	
293.2	12.136
473.2	14.172
DATA SET 9*	
293.2	14.440
473.2	17.428

T	ρ
DATA SET 10*	
4.2	2.07
DATA SET 11*	
4.2	2.12
DATA SET 12*	
4.2	2.10
DATA SET 13*	
4.2	6.50
DATA SET 14*	
4.2	6.63
DATA SET 15*	
4.2	7.21
DATA SET 16*	
4.2	7.41
DATA SET 17*	
4.2	7.57
DATA SET 18*	
4.2	2.10
DATA SET 19*	
4.2	7.49
DATA SET 20*	
4.2	7.617
DATA SET 21*	
4.2	7.995

T	ρ
DATA SET 22*	
4.2	7.461
Ann. Temp. (K)	ρ
DATA SET 23* (T = 4.2 K)	
300	7.468
373	7.450
693	7.463
713	7.404
T	ρ
DATA SET 24*	
4.2	7.350
Ann. Temp. (K)	ρ
DATA SET 25* (T = 4.2 K)	
300	7.586
422	7.475
552	7.498
673	7.542
797	7.456
920	7.453
1202	7.441
DATA SET 26* (T = 4.2 K)	
360	7.567
564	7.536
565	7.536
567	7.498
570	7.498
DATA SET 27* (T = 4.2 K)	
344	7.644
670	7.625
661	7.612

Ann. Temp. (K)	ρ
DATA SET 27 (cont.)* (T = 4.2 K)	
660	7.601
732	7.553
1308	7.576
T	ρ
DATA SET 28	
1.1	1.066
4.2	1.066
77	1.302
273	2.670
DATA SET 29*	
1.1	1.071
4.2	1.067
77	1.301
273	2.664
DATA SET 30*	
1.1	1.069
4.2	1.069
77	1.304
273	2.663
DATA SET 31*	
1.1	1.066
4.2	1.066
77	1.294
273	2.660
DATA SET 32*	
4.2	1.064
77	1.306
273	2.665
DATA SET 33	
270	18.7
370	24.2
470	30.8

T	ρ
DATA SET 33 (cont.)	
570	39.0
645	47.5
775	54.5
870	60.5
970	67.5
1080	76.0
DATA SET 34	
285	14.7
390	17.8
560	24.0
650	28.3
770	36.0
870	43.5
975	53.7
1075	64.0
DATA SET 35	
280	13.5
360	15.8
490	20.2
660	27.0
780	32.5
880	38.3
970	44.5
1080	52.6
DATA SET 36	
255	13.3
390	16.5
560	22.2
793	32.2
880	35.5
982	41.2
1082	47.0
DATA SET 37	
270	14.5
375	17.2
470	19.8
575	23.2
680	26.5

T	ρ
DATA SET 37 (cont.)	
772	31.0
875	35.0
973	39.8
1072	45.3
DATA SET 38	
275	15.0
375	18.4
475	21.7
575	25.2
680	29.0
780	33.0
875	37.1
975	42.0
1075	47.5*
1205	54.0
1275	49.0
1315	53.0
DATA SET 39	
275	13.0
375	16.5
480	20.1
575	22.8
675	25.0
765	30.3
875	30.8
970	34.7
1050	38.0
1110	40.0
1175	38.0
1255	31.7
1300	35.3
DATA SET 40	
300	12.3
375	13.9
475	16.3
575	18.7
630	19.4
675	19.9
825	29.2
865	28.5

* Not shown in figure.

TABLE 5. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + ALUMINUM ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 40 (cont.)	
970	31.8
1030	34.5
1170	31.9
1295	37.0
DATA SET 41	
318	11.0
375	12.3
475	14.8
575	16.9
675	16.3
775	21.3
825	24.9
872	24.3
972	26.5
1050	28.6
1140	27.0
1170	28.0
1300	32.7
DATA SET 42	
299	11.2
375	13.0
475	15.5
575	18.0
675	19.0
775	21.3*
825	27.2
875	25.3
975	28.0
1050	30.5
1072	29.4
1172	31.4*
1290	35.0
DATA SET 43	
4.0	8.00
79.0	8.40
164.0	9.35
198.0	9.73
236.0	10.31
273.0	10.50
322.0	10.97
DATA SET 44	
293.2	7.14
DATA SET 45	
293.2	9.25
DATA SET 46*	
293.2	10.35
DATA SET 47*	
293.2	11.29
DATA SET 48	
20	1.501
78	1.641
299	6.61
DATA SET 49	
4.2	0.76
295	6.5
DATA SET 50	
302	2.80
367	3.27
459	3.91
577	4.82
690	5.82
792	7.03
DATA SET 51	
302	6.26
383	7.07
446	7.62
467	7.81*
574	8.79
673	9.71
773	10.70
DATA SET 52	
307	10.71
354	11.08
DATA SET 52 (cont.)	
479	12.15
600	13.51
720	14.81
817	16.00
DATA SET 53	
303	12.97
355	13.40
459	14.26
582	15.46
697	16.62
779	17.87
DATA SET 54	
288	5.47
315	5.80
364	6.37
394	6.68
423	7.05
460	7.53
490	7.93
511	8.24
553	8.92
593	9.72
644	10.81
699	12.24
774	14.26
807	15.47
DATA SET 55	
1.1	7.868
4.2	7.867
77	8.253
273	10.19
DATA SET 56*	
1.1	7.850
4.2	7.853
77	8.250
273	10.16
DATA SET 57*	
1.1	7.806
DATA SET 57 (cont.)*	
4.2	7.806
77	8.204
273	10.10
DATA SET 58*	
1.1	7.813
4.2	7.813
77	8.217
273	10.14
DATA SET 59*	
1.1	7.889
4.2	7.889
77	8.288
273	10.16
DATA SET 60*	
4.2	7.891
77	8.273
273	10.21
DATA SET 61*	
4.2	2.080
DATA SET 62*	
4.2	2.109
DATA SET 63*	
4.2	7.61
DATA SET 64*	
4.2	7.62
DATA SET 65*	
4.2	0.93
DATA SET 66*	
4.2	2.89
DATA SET 67*	
298.2	10.75
DATA SET 68*	
298.2	[illegible].91
DATA SET 69*	
298.2	10.70
DATA SET 70*	
298.2	12.03
DATA SET 71*	
1373	33.6
1473	35.0
DATA SET 72*	
1373	43.1
1473	41.8
DATA SET 73*	
1373	47.8
1473	46.8
DATA SET 74*	
1373	58.6
1473	57.4
DATA SET 75*	
1373	59.6
1473	58.2
DATA SET 76*	
1373	61.1
1473	59.6
DATA SET 77*	
1373	63.7
1473	62.1
DATA SET 78*	
1373	66.7
1473	64.9
DATA SET 79*	
1373	71.3
1473	70.0
DATA SET 80*	
1373	74.5
1473	72.8
DATA SET 81*	
1373	75.4
1473	74.2
DATA SET 82*	
1373	70.0
1473	68.6
DATA SET 83*	
1373	69.6
1473	68.1
DATA SET 84*	
1373	64.5
1473	63.4
DATA SET 85*	
1373	49.5
1473	51.3
DATA SET 96	
297	10.41
317	10.61
336	10.74*
354	10.97*
375	11.14
395	11.33*
415	11.48
442	11.61*

* Not shown in figure.

TABLE 5. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + ALUMINUM ALLOYS (Temperature Dependence) (continued)

DATA SET 86 (cont.)

T	ρ
460	12.00
484	12.23*
504	12.44*
520	12.61
540	12.89*
564	13.20*
595	13.44
626	13.96*
646	14.18
669	14.46*
681	14.66*
702	14.90
723	15.18*
745	15.47
763	15.74*
786	16.04

DATA SET 87

T	ρ
300	10.49*
335	10.82
372	11.20*
391	11.37
416	11.59*
433	11.73
450	11.94
472	12.18*
490	12.36
509	12.56*
529	12.82
548	13.05*
573	13.34*
600	13.64*
611	13.82
633	14.02*
652	14.30*
673	14.53
691	14.77*
712	15.05*
731	15.32*
750	15.59*
772	15.88

DATA SET 88

T	ρ
298.7	10.07
313.5	10.16*
324.0	10.24*

DATA SET 88 (cont.)

T	ρ
332.9	10.33*
338.6	10.38*
342.9	10.42*
347.7	10.47
354.1	10.53*
358.4	10.58*
363.9	10.66*
368.8	10.71
373.0	10.79*
379.0	10.84*
384.9	10.90*
388.7	10.95*
393.7	11.02*
399.2	11.05
403.2	11.10*
409.1	11.16*
412.5	11.20*
417.4	11.25*
423.4	11.30
434.4	11.39*
444.6	11.48*
454.6	11.56*
463.3	11.64*
474.4	11.74

DATA SET 89*

T	ρ
300.2	10.52
313.3	10.61
323.8	10.67
333.1	10.77
338.1	10.83
343.1	10.88
348.0	10.92
353.1	10.95
358.0	10.97
363.5	10.99
368.0	11.00
373.0	11.02
379.2	11.02
384.5	11.02
388.7	11.04
393.1	11.05
398.3	11.09
403.5	11.13

DATA SET 90*

T	ρ
297.6	10.10
314.0	10.23
322.9	10.32
332.9	10.41
338.9	10.45
344.3	10.50
348.4	10.54
353.5	10.59
358.8	10.65
364.1	10.69
368.8	10.75

DATA SET 91*

T	ρ
334.2	10.71
338.6	10.73
343.7	10.72
347.9	10.71
353.2	10.70
358.8	10.73
363.7	10.76
367.8	10.81
372.6	10.85
378.3	10.88
383.5	10.92
387.7	10.97

DATA SET 92*

T	ρ
298.2	11.10
303.3	11.14
308.7	11.17
312.9	11.20
317.8	11.22
328.9	11.29
332.9	11.33
338.4	11.37
343.3	11.42
348.8	11.46
353.7	11.51
358.9	11.56
363.4	11.60
367.0	11.64
373.7	11.68
378.4	11.73
383.6	11.77
388.2	11.82
393.6	11.86

DATA SET 92 (cont.)*

T	ρ
398.5	11.92
403.2	11.98
407.7	12.02
412.6	12.07
419.0	12.15
424.0	12.20
428.6	12.25
434.1	12.32
438.1	12.36
443.9	12.42
448.8	12.47
452.4	12.53
458.3	12.59
463.1	12.65
468.9	12.69
473.0	12.73

DATA SET 93*

T	ρ
299.0	11.48
303.2	11.55
308.9	11.59
313.4	11.62
319.6	11.65
322.3	11.70
328.1	11.72
333.8	11.76
339.1	11.78
344.3	11.80
348.4	11.84
352.9	11.85
357.7	11.88
362.0	11.89
368.3	11.92
373.2	11.94
378.3	11.94
383.8	11.95
388.4	11.96
393.5	11.97
398.3	12.00
402.4	12.03
407.7	12.08
412.8	12.11

DATA SET 94

T	ρ
299.1	11.04*
303.5	11.09*

DATA SET 94 (cont.)

T	ρ
309.5	11.12
314.8	11.17*
323.5	11.28*
327.3	11.34*
332.1	11.37
336.8	11.42*
341.1	11.47*
347.9	11.51*
353.6	11.58
358.6	11.63*
362.7	11.68*
367.9	11.73*
372.8	11.76
379.3	11.80*
383.8	11.87*
387.1	11.90*
397.7	12.02
404.3	12.09*
408.5	12.13*
412.0	12.16*
418.7	12.23*
422.9	12.27
428.4	12.33*
433.9	12.38*
438.0	12.43*
442.6	12.48
446.6	12.52*
452.0	12.58*
457.7	12.63*
462.8	12.69*
467.0	12.73*
471.9	12.76

DATA SET 95*

T	ρ
295.9	11.52
303.1	11.60
308.0	11.64
312.2	11.68
316.8	11.71
323.5	11.74
333.2	11.72
339.5	11.71
344.2	11.70
349.3	11.68
353.3	11.66
358.6	11.67

DATA SET 96*

T	ρ
311	10.15
321	10.22
332	10.30
342	10.41
352	10.47
361	10.57
371	10.67
379	10.75
390	10.84
399	10.93
412	11.04
418	11.11
427	11.20
437	11.29
448	11.35
458	11.44
469	11.55
479	11.63
490	11.73
498	11.79
510	11.89
520	12.02
529	12.13
537	12.24
549	12.35
557	12.46
565	12.55
578	12.68
586	12.86

DATA SET 97

T	ρ
307	10.43
337	10.75
365	11.04
395	11.31*
424	11.57
444	11.78*
457	11.87*
468	11.94*
478	12.02*
487	12.12
498	12.17*
507	12.25*
518	12.32*
527	12.40*
537	12.47
546	12.56*

* Not shown in figure.

TABLE 5. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + ALUMINUM ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 97 (cont.)	
557	12.65*
573	12.81
598	13.03
627	13.35
655	13.58
672	13.74*
687	13.88
703	14.04*
719	14.18
762	14.71
DATA SET 98*	
307	11.12
326	11.29
347	11.49
364	11.67
387	11.89
404	12.04
425	12.31
444	12.37
463	12.51
473	12.60
484	12.68
493	12.75
503	12.80
513	12.85
523	12.90
533	12.94
543	12.98
553	13.02
569	13.12
584	13.19
603	13.41
623	13.61
643	13.81
662	13.95
680	14.03
701	14.12
722	14.28
740	14.50
772	14.82
DATA SET 99*	
446	11.72
457	11.81
469	11.87

T	ρ
DATA SET 99 (cont.)*	
477	11.94
491	12.03
502	12.11
512	12.19
522	12.26
532	12.37
542	12.47
552	12.57
567	12.73
DATA SET 100	
475	12.50
482	12.56*
493	12.61
503	12.66*
513	12.68*
524	12.73*
533	12.83*
543	12.91
563	13.08
DATA SET 101	
1381	25.55
1398	26.11*
1416	26.40*
1430	26.40*
1451	27.35
1470	27.35
1520	28.34
1529	28.66
1557	29.42
DATA SET 102	
4.2	7.54
DATA SET 103*	
4.2	6.79
DATA SET 104*	
4.2	6.88
DATA SET 105	
4.2	6.69

T	ρ
DATA SET 106*	
673	32.6
1020	55.0
1023	56.2

* Not shown in figure.

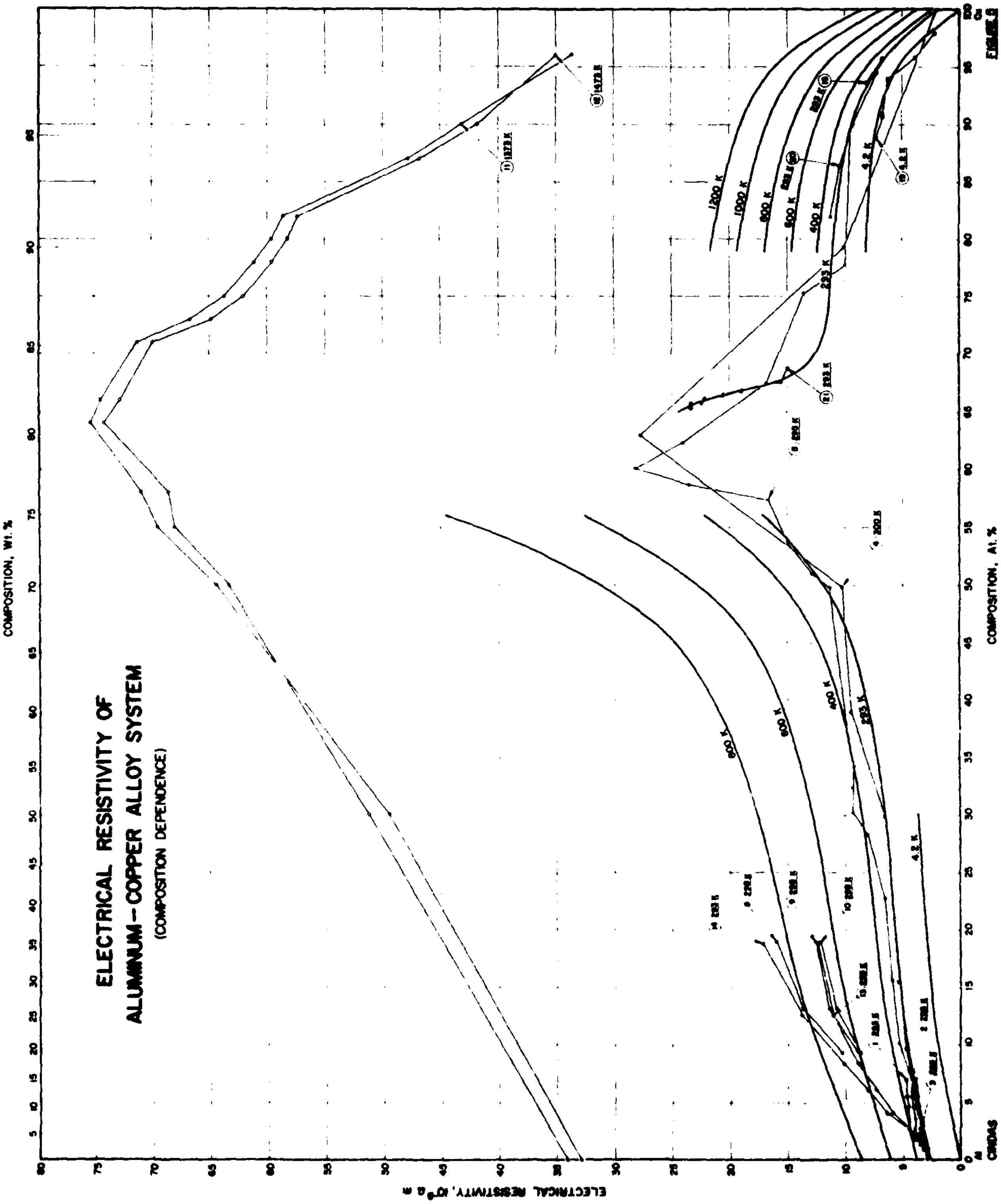

ELECTRICAL RESISTIVITY OF
ALUMINUM-COPPER ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION, Wt. %
COMPOSITION, At. %
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
1200 K
1000 K
900 K
800 K
600 K
400 K
293 K
4.2 K

TABLE 6. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM (Composition Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (at.% of Cu)	Composition (weight percent), Specifications, and Remarks
1	94	Vozdvizhenskii, V.M.	1961		293.2	0.1-15	5.8 mm diameter x 60 mm long; cast; annealed at 819 K for 70 hr.
2	94	Vozdvizhenskii, V.M.	1961		293.2	1.7-7.0	Similar to the above specimens except annealed at 773 K for 200 hr.
3	94	Vozdvizhenskii, V.M.	1961		293.2	1.5-7.0	Similar to the above specimens except annealed at 723 K for 230 hr.
4	55	Smith, A.W.	1925	B	300	0-100	Specimens 1.9 cm in diameter and 10 cm long; prepared by melting 99.97* pure aluminum and copper supplied by Baker.
5	95	Aliev, N.A.	1953		295.2	4.6-89	No details reported.
6*	82	Turnbull, D., Rosenbaum, H.S., and Treaftis, H.N.	1960		273.2	0.4-2.2	Specimens 0.025 cm diameter x 25 cm long in the form of a coil 0.32 cm in diameter and 3.8 cm long; fabricated by cold-swaging, drawing, and rolling; homogenized at 823 K and quenched to 223 K.
7*	96	Bradley, J.M. and Stringer, J.	1974	A	293.2	0.2-1.5	40 x 5 x 0.5 mm; prepared from 99.999 pure metals by melting and homogenizing in vacuum, obtained ingots cold-rolled to 0.5 mm thick, cut to size; solution-treated at 773 K and water quenched immediately prior to tests.
8	97	Köster, W. and Rave, H.-P.	1961		298.2	9.3-19	Cold worked.
9	97	Köster, W. and Rave, H.-P.	1961		298.2	9.3-19	Recrystallized at 873 K for 20 min.
10	97	Köster, W. and Rave, H.-P.	1961		298.2	9.3-19	Ordered.
11	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1373	0-96	Alloys prepared from 99.95 pure electrolytic copper and 99.9 pure aluminum; in liquid state.
12	91	Eretnov, K.I. and Lyubimov, A.P.	1967		1473	0-96	The above specimens.
13	98	Köster, W. and Rave, H.-P.	1964		293.2	1.0-19	Alloys recrystallized; measuring temperature not given, assigned here as 20 C.
14	98	Köster, W. and Rave, H.-P.	1964		293.2	1.0-19	The above specimens 90% cold-worked.
15*	62	Gulyaev, A.P. and Trusova, E.F.	1950		293.2	0.3-0.9	Measuring temperature assigned here as 20 C.
16	62	Gulyaev, A.P. and Trusova, E.F.	1950		293.2	94,96	Similar to the above specimens.
17*	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	673.2	0-33	Alloys in solid state.
18*	87	Korol'kov, A.M. and Shashkov, D.P.	1962	R	1023	0-33	The above specimens in liquid state.
19	74	Charsley, P. and Salter, J.A.M.	1965	A	4.2	89-98	Polycrystalline specimens; grain size 0.1 to 0.3 mm; 3 mm diameter x 12 cm long; prepared by International Research and Development Co.; cast, machined, swaged, and drawn; annealed in vacuo at 1023 K for at least 14 hr and furnace cooled.
20	63	Linde, J.O.	1954	B	293.2	82-94	Specimens prepared from Johnson, Matthey spectroscopically standardized pure metals by melting together; rolled, homogenized at 1173 K for about 10 hr, and rolled to about 0.4 mm^2 in cross-section; annealed in vacuum at 723 to 773 K for 15 hr, cooled slowly.

* Not shown in figure.

TABLE 6. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (at.% of Cu)	Composition (weight percent), Specifications, and Remarks
21	66	Hishiyama, Y.	1967	A	293.2	65.25–68.65	Compositions calculated from electron to atom ratios of 1.695, 1.684, 1.685, 1.679, 1.672, 1.664, 1.648, and 1.627 for specimens in increasing order of Cu content; γ-phase specimens 1.5 x 1.5 x 20 mm³ prepared from 99.9 pure constituents by induction heating under flux of sodium and potassium chloride salt bath in high-purity graphite crucible, imbedding the 20g ingots in high-purity graphite flour in order to prevent volatilization, sealing in quartz or glass tubes in vacua, annealing at 973 K for 7 days, furnace cooling, and checking homogeneity and concentration by chemical analysis; due to excessive brittleness specimens were ground on emery paper rather than cut by usual techniques; data extracted from table.

TABLE 7. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF ALUMINUM-COPPER ALLOY SYSTEM (Composition Dependence)

[Composition, C, a/o Cu; Electrical Resistivity, ρ, 10^{-8} Ωm]

C	ρ
DATA SET 1 (T = 293.2 K)	
0.04	2.61*
0.09	2.69*
0.34	2.80
0.43	2.90*
0.64	2.99*
0.86	3.15
1.08	3.36*
1.30	3.50
1.52	3.71*
1.74	3.98*
1.96	4.02
2.19	4.19*
2.64	4.42
3.56	4.44*
4.51	4.59
5.47	4.67
6.97	4.75
DATA SET 2 (T = 293.2 K)	
1.74	3.94
1.96	3.95
2.19	3.99
2.64	3.96
3.56	3.98
4.51	4.12
5.47	4.24
6.97	4.28
DATA SET 3 (T = 293.2 K)	
1.52	3.51
1.74	3.52*
1.96	3.52*
2.19	3.53
2.64	3.47
3.56	3.57
4.51	3.64
5.47	3.78
6.97	3.86
DATA SET 4 (T = 300 K)	
0	2.96
4.5	3.85
9.6	4.78
15.4	5.40
29.8	6.54
38.9	9.43
49.8	10.25
62.9	27.78
79.3	10.02
100	1.97
DATA SET 5 (T = 295.2 K)	
4.62	4.72*
10.02	5.32
15.58	5.98
22.64	6.55
28.14	8.06
30.18	9.36
32.36	9.31
34.15	9.24
38.52	10.02
49.73	11.30
50.95	12.90
53.42	14.90
57.33	16.61
58.68	23.53
60.06	28.25
62.32	24.04
67.44	16.81
75.27	13.51
77.86	9.96
88.98	9.52
DATA SET 6* (T = 273.2 K)	
0.4	2.82
0.8	3.20
1.3	3.69
1.6	3.95
1.7	3.76
2.2	3.82
2.2	3.97
DATA SET 7* (T = 293.2 K)	
0.2	2.84
0.4	3.02
0.5	3.15
0.6	3.17
0.8	3.36
1.0	3.55
1.2	3.65
1.5	3.74
DATA SET 8 (T = 298.2 K)	
9.3	10.3
13.1	13.7
18.9	16.0
DATA SET 9 (T = 298.2 K)	
9.3	8.95
13.1	11.5
18.9	12.6
DATA SET 10 (T = 298.2 K)	
9.3	8.7
13.1	10.8
18.9	12.2
DATA SET 11 (T = 1373 K)	
0	32.9
30	49.5
50	64.5
55	69.6
58	71.0
64	75.4
66	74.5
71	71.3
73	66.7
75	63.7
78	61.1
80	59.6
DATA SET 11 (cont.) (T = 1373 K)	
82	58.6
87	47.8
90	43.1
96	33.6
DATA SET 12 (T = 1473 K)	
0	34.1
30	51.3
50	63.4
55	68.1
58	68.6
64	74.2
66	72.8
71	70.0
73	64.9
75	62.1
76	59.6
80	58.2
82	57.4
87	46.8
90	41.8
96	35.0
DATA SET 13 (T = 293.2 K)	
1.0	2.89
2.0	4.24*
4.0	5.99
6.0	7.32
8.3	8.91
12.5	11.08
18.7	12.44
DATA SET 14 (T = 293.2 K)	
1.0	3.06*
2.0	4.52
4.0	6.43
6.0	8.02
8.3	10.17
12.5	13.79
18.7	17.18
DATA SET 15* (T = 293.2 K)	
0.26	3.18
0.52	3.31
0.87	3.61
DATA SET 16 (T = 293.2 K)	
93.55	8.05
95.7	6.64
DATA SET 17* (T = 673.2 K)	
0	15.0
0.64	18.1
1.16	20.8
2.41	28.4
5.23	17.5
9.60	14.4
13.46	14.0
17.43	16.2
20.58	13.4
25.09	12.7
33.27	32.6
DATA SET 18* (T = 1023 K)	
0	54.7
0.64	57.6
1.16	65.5
2.41	71.8
5.23	51.8
9.60	46.3
13.46	44.6
17.43	50.0
20.58	47.3
25.09	48.3
33.27	56.2
DATA SET 19 (T = 4.2 K)	
88.75	7.21
90.60	6.62
DATA SET 19 (cont.) (T = 4.2 K)	
90.88	6.63
93.90	5.20
95.78	3.88
97.91	2.12
DATA SET 20 (T = 293.2 K)	
81.9	11.29
86.4	10.35
90.0	9.25
94.4	7.14
DATA SET 21 (T = 293.2 K)	
65.25	23.4
65.65	23.4
65.75	22.5
66.05	22.2
66.40	20.6
66.80	19.0
67.60	15.6
68.65	15.0

* Not shown in figure.

3.2. Aluminum-Magnesium Alloy System

The aluminum-magnesium alloy system does not form a continuous series of solid solutions. The maximum solid solubility of magnesium in aluminum is 17.4% (18.9 at.%) at 723 K and the solubility decreases at higher and lower temperatures, being only 1.9% (2.1 at.%) at 373 K. The maximum solid solubility of aluminum in magnesium is 12.7% (11.6 at.%) at 710 K and likewise it decreases at higher and lower temperatures, being only about 1.5% (1.3 at.%) at 373 K. Thus the region of solid solution for this system is even more limited than that of the aluminum-copper alloy system.

There are 76 sets of experimental electrical resistivity data available for this system. Of the 43 data sets for Al + Mg alloys listed in table 9, tabulated in table 10, and shown in figure 8, 11 sets are merely single data points. Twelve of the 28 data sets for Mg + Al alloys listed in table 11, tabulated in table 12, and shown in figure 9 are single data points. Of the 5 resistivity-composition data sets listed in table 13, tabulated in table 14, and shown in figure 10, one set is for specimens in liquid state.

For the Al + Mg alloys, measurements were limited to alloys containing no more than 14% Mg. Recommended values were, therefore, generated only for 0.5 to 10% Mg alloys. For the electrical resistivity of these alloys, it appears that the deviation from the Matthiessen's rule due to alloying is small. Hence, a residual resistivity versus composition curve was constructed based on the slope of the data of Gulyaev and Trusova [62] (Al-Mg data set 4) measured at 293 K, and the total electrical resistivity of each alloy was then obtained by adding its residual electrical resistivity to the intrinsic electrical resistivity of pure Al [54]. The resulting recommended values agree well with the data of Hase et al. [99] (Al + Mg data sets 1-4) and of Cordier and Detert [100] (Al + Mg data sets 12-14) above room temperature, and agree with the data of Seth and Wood [101] (Al + Mg data sets 9-11), Clark et al. [102,103] (Al + Mg data sets 15, 26, 27), and Clark and Tryon [104] (Al + Mg data sets 28-36) between 100 K and 300 K.

For the Mg + Al alloys, no measurements were made for alloys containing more than 12.2% Al. Accordingly, the recommended values were generated for 0.5 to 10% Al alloys only. For the electrical resistivity of these alloys, the deviation from the Matthiessen's rule due to alloying appears also to be

small. The residual resistivity values of these alloys were derived based on the data of Smith [55] (Al-Mg data set 5) measured at 292 K, and the total electrical resistivity of each alloy was obtained by adding its residual resistivity to the intrinsic electrical resistivity of pure Mg [51]. The resulting recommended values agree with the data of Staebler [105] (Mg + Al data sets 19-21) and of Powell et al. [106] (Mg + Al data set 28) above room temperature, and with the data of Hedgecock and Muir [107] (Mg + Al data sets 1-3) and Seth and Wood [101] (Mg + Al data sets 4-6) below room temperature.

The resulting recommended electrical resistivity values for Al, Mg, and for 10 Al-Mg binary alloys are presented in table 8 and shown in figures 6, 7, and 10. No values were generated for alloys containing 15 to 85% Mg. The recommended values for Al and for Mg are for well-annealed high-purity specimens, but those values for temperatures below about 100 K are applicable only to Al and Mg having residual electrical resistivities as given at 1 K in table 8. The alloys for which the recommended values are generated are not ordered and have not been quenched or cold-worked severely. The recommended values cover a full range of temperature from 1 K to the solidus temperature of the alloy where melting starts. These values are not corrected for the thermal expansion of the material. The estimated uncertainties in the values for the various alloys and for different temperature ranges are explicitly stated in a footnote to table 8. Some of the values in table 8 are indicated as provisional because their uncertainties are greater than ±5%.

TABLE 8. RECOMMENDED ELECTRICAL RESISTIVITY OF ALUMINUM-MAGNESIUM ALLOY SYSTEM†

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Al : 100.00% (100.00 At.%) Mg: 0.00% (0.00 At.%)		Al : 99.50% (99.45 At.%) Mg: 0.50% (0.55 At.%)		Al : 99.00% (98.89 At.%) Mg: 1.00% (1.11 At.%)		Al : 97.00% (96.68 At.%) Mg: 3.00% (3.32 At.%)		Al : 95.00% (94.48 At.%) Mg: 5.00% (5.52 At.%)		Al : 90.00% (89.02 At.%) Mg: 10.00% (10.98 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	0.00100*	1	0.254*‡	1	0.512*‡	1	1.53*‡	1	2.54*‡	1	4.93*‡
4	0.00100	4	0.254*‡	4	0.512‡	4	1.53*‡	4	2.54‡	4	4.93*‡
7	0.00100	7	0.254*‡	7	0.512‡	7	1.53*‡	7	2.54‡	7	4.93*‡
10	0.00103	10	0.254*‡	10	0.512‡	10	1.53*‡	10	2.54‡	10	4.93*‡
15	0.00117	15	0.254*‡	15	0.512‡	15	1.53*‡	15	2.54‡	15	4.93*‡
20	0.00168	20	0.255*‡	20	0.513‡	20	1.53*‡	20	2.54‡	20	4.93*‡
25	0.00296	25	0.256‡	25	0.514‡	25	1.53*‡	25	2.54‡	25	4.93*‡
30	0.00564	30	0.259‡	30	0.517‡	30	1.54*‡	30	2.55‡	30	4.94*‡
40	0.0188	40	0.273‡	40	0.531‡	40	1.55*‡	40	2.56‡	40	4.95*‡
50	0.0480	50	0.302‡	50	0.561‡	50	1.58*‡	50	2.58‡	50	4.99*‡
60	0.0960	60	0.351‡	60	0.609‡	60	1.63*‡	60	2.64‡	60	5.04*‡
70	0.163	70	0.418‡	70	0.673‡	70	1.70*‡	70	2.71‡	70	5.12*‡
80	0.246	80	0.500‡	80	0.754‡	80	1.78*‡	80	2.80‡	80	5.21*‡
90	0.340	90	0.595‡	90	0.851‡	90	1.88*‡	90	2.90‡	90	5.31‡
100	0.443	100	0.697‡	100	0.958‡	100	1.98*‡	100	3.01‡	100	5.42‡
150	1.010	150	1.27‡	150	1.53‡	150	2.56*‡	150	3.59‡	150	6.02‡
200	1.593	200	1.85‡	200	2.11‡	200	3.15*‡	200	4.19‡	200	6.63‡
250	2.167	250	2.43	250	2.69	250	3.74*	250	4.78	250	7.24
273	2.429	273	2.69	273	2.96	273	4.01*	273	5.05	273	7.52
293	2.653	293	2.92	293	3.18	293	4.23	293	5.28	293	7.76
300	2.731	300	2.99	300	3.26	300	4.31	300	5.36	300	7.85
350	3.292	350	3.56*	350	3.82*	350	4.88*	350	5.93	350	8.43
400	3.854	400	4.12*	400	4.39*	400	5.45*	400	6.51	400	9.02
500	4.992	500	5.26*	500	5.53*	500	6.59*	500	7.67	500	10.2
600	6.155	600	6.42*	600	6.69*	600	7.75*	600	8.86	600	11.4
700	7.353	700	7.62*	700	7.90*	700	8.97*	700	10.1*	700	12.6*
800	8.622	800	8.90*	800	9.18*	800	10.3*	800	11.4*	789	13.7*
900	10.019	900	10.3	900	10.6	880	11.4*	849	12.1*		
933.52	10.516*	923	10.6	913	10.8						

† Uncertainties in the electrical resistivity values are as follows:

100.00 Al - 0.00 Mg: ±2% below 80 K, ±1% from 80 to 200 K, ±0.5% above 200 K to 500 K, and ±2% above 500 K.
99.50 Al - 0.50 Mg: ±10% up to 200 K and ±5% above 200 K.
99.00 Al - 1.00 Mg: ±10% up to 200 K and ±5% above 200 K.
97.00 Al - 3.00 Mg: ±10% up to 200 K and ±5% above 200 K.
95.00 Al - 5.00 Mg: ±10% up to 200 K and ±5% above 200 K.
90.00 Al - 10.00 Mg: ±10% up to 200 K and ±5% above 200 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 8. RECOMMENDED ELECTRICAL RESISTIVITY OF ALUMINUM-MAGNESIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Al: 10.00% (9.10 At.%) Mg: 90.00% (90.90 At.%)		Al: 5.00% (4.53 At.%) Mg: 95.00% (95.47 At.%)		Al: 3.00% (2.71 At.%) Mg: 97.00% (97.29 At.%)		Al: 1.00% (0.90 At.%) Mg: 99.00% (99.10 At.%)		Al: 0.50% (0.45 At.%) Mg: 99.50% (99.55 At.%)		Al: 0.00% (0.00 At.%) Mg: 100.00% (100.00 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	13.1*	1	9.02*	1	5.64*	1	1.87*	1	0.936*	1	0.0062
4	13.1	4	9.02	4	5.64	4	1.87	4	0.936	4	0.0062
7	13.1	7	9.02	7	5.64	7	1.87	7	0.937	7	0.0064
10	13.1	10	9.02	10	5.64	10	1.87	10	0.937	10	0.0069
15	13.1	15	9.02	15	5.64	15	1.87	15	0.939	15	0.0086‡
20	13.1	20	9.03	20	5.65	20	1.88	20	0.942	20	0.0124‡
25	13.1	25	9.04	25	5.66	25	1.89	25	0.949	25	0.0194‡
30	13.1	30	9.05	30	5.67	30	1.90	30	0.960	30	0.0310
40	13.1	40	9.09	40	5.70	40	1.94	40	1.00	40	0.0746
50	13.2	50	9.17	50	5.78	50	2.02	50	1.08	50	0.152
60	13.3	60	9.28	60	5.90	60	2.14	60	1.19	60	0.262
70	13.4	70	9.42	70	6.04	70	2.27	70	1.34	70	0.400
80	13.6	80	9.58	80	6.20	80	2.43	80	1.50	80	0.559
90	13.8	90	9.75	90	6.37	90	2.60	90	1.67	90	0.731
100	14.0	100	9.93	100	6.55	100	2.78	100	1.85	100	0.912
150	14.9	150	10.9	150	7.50	150	3.73	150	2.80	150	1.84
200	15.8	200	11.8	200	8.42	200	4.65	200	3.72	200	2.75
250	16.7	250	12.7	250	9.30	250	5.53	250	4.59	250	3.61
273	17.1	273	13.1	273	9.69	273	5.92	273	4.98	273	4.05
293	17.4	293	13.4	293	10.0	293	6.25	293	5.31	293	4.39
300	17.6	300	13.5	300	10.1	300	6.37	300	5.43	300	4.51
350	18.4	350	14.3	350	11.0	350	7.20	350	6.26	350	5.36
400	19.2	400	15.2	400	11.8*	400	8.03	400	7.10*	400	6.18
500	20.9*	500	16.9*	500	13.5*	500	9.74	500	8.79*	500	7.82
600	22.7*	600	18.6*	600	15.2*	600	11.5	600	10.5*	600	9.44
700	24.4*	700	20.4*	700	17.0*	700	13.2	700	12.3*	700	11.0
756	25.2*	800	22.1*	800	18.7*	800	14.9*	800	14.0*	800	12.6
		839	22.7*	872	20.0*	900	16.6*	900	15.7*	900	14.2
						903	16.6*	913	15.9*	922	14.5(s)
										923	26.1‡ (ℓ)
										1000	26.0‡
										1100	25.8‡
										1200	25.6‡

† Uncertainties in the electrical resistivity values are as follows:

10.00 Al - 90.00 Mg: ±5% below 200 K, ±3% from 200 to 600 K, and ±5% above 600 K.
5.00 Al - 95.00 Mg: ±5% below 200 K, ±3% from 200 to 600 K, and ±5% above 600 K.
3.00 Al - 97.00 Mg: ±5% below 200 K, ±3% from 200 to 600 K, and ±5% above 600 K.
1.00 Al - 99.00 Mg: ±5% below 200 K, ±2% from 200 to 600 K, and ±5% above 600 K.
0.50 Al - 99.50 Mg: ±5% below 200 K, ±2% from 200 to 600 K, and ±5% above 600 K.
0.00 Al - 100.00 Mg: ±5% up to 10 K, ±8% between 10 and 30 K, ±5% from 30 to 100 K, ±3% above 100 K to 600 K, ±5% above 600 K to 922 K, and ±10% above 922 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

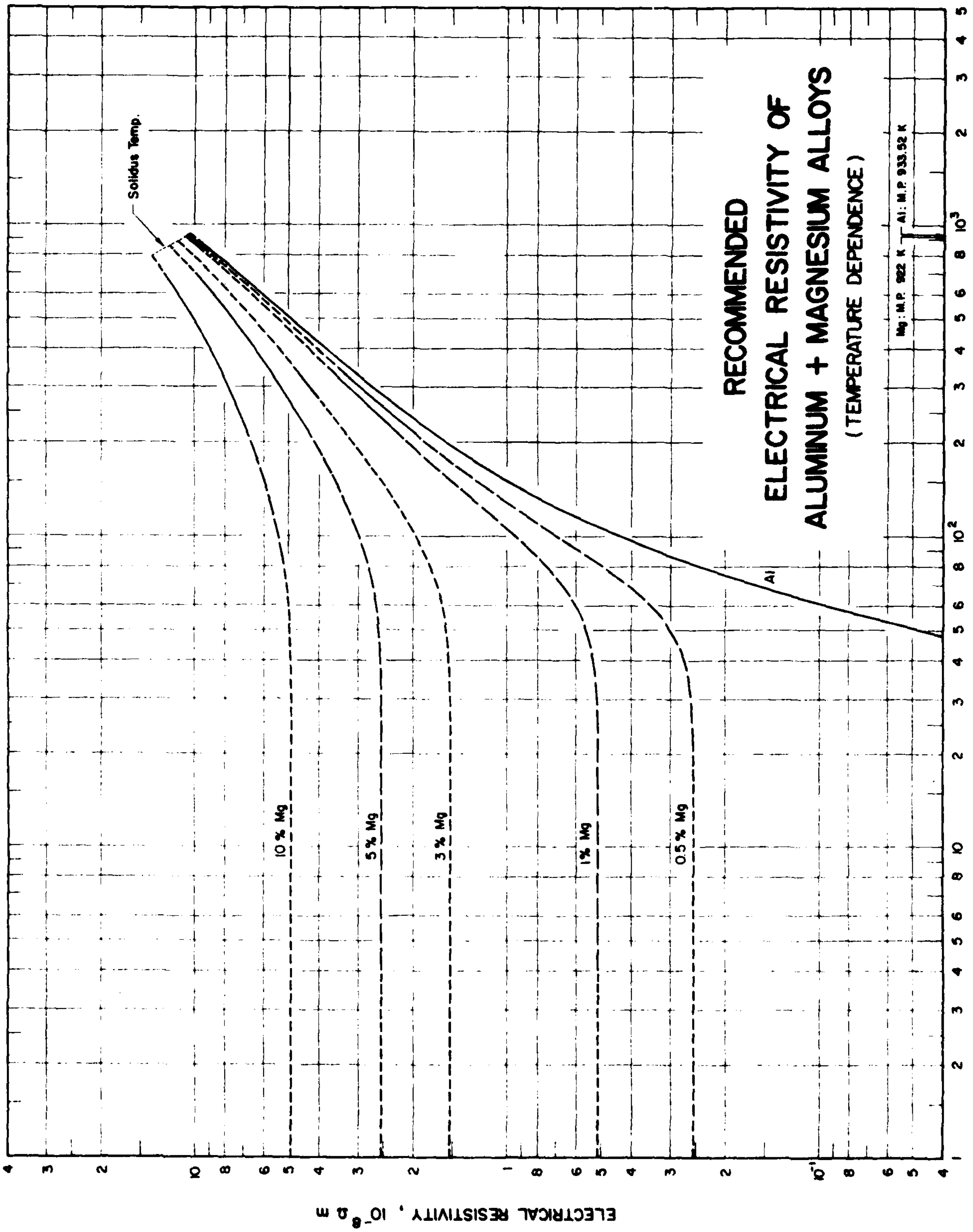

RECOMMENDED
ELECTRICAL RESISTIVITY OF
ALUMINUM + MAGNESIUM ALLOYS
(TEMPERATURE DEPENDENCE)
Solidus Temp.
10 % Mg
5 % Mg
3 % Mg
1% Mg
0.5 % Mg
Al
Mg: M.P. 922 K
Al: M.P. 933.52 K
TEMPERATURE, K
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
CINDAS

FIGURE 6

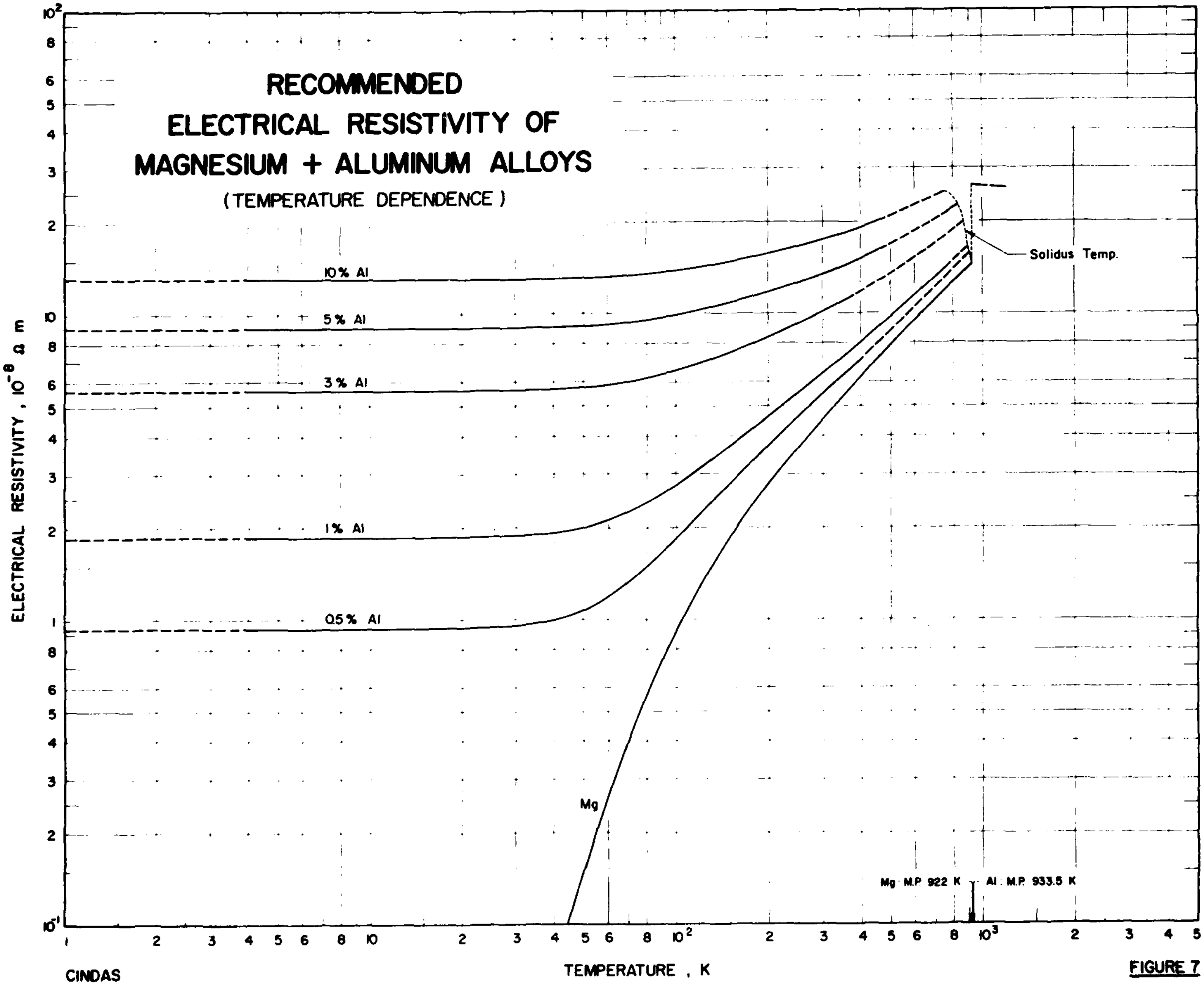

RECOMMENDED
ELECTRICAL RESISTIVITY OF
MAGNESIUM + ALUMINUM ALLOYS
(TEMPERATURE DEPENDENCE)
10% Al
5% Al
3% Al
1% Al
0.5% Al
Mg
Solidus Temp.
Mg M.P. 922 K
Al M.P. 933.5 K
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE, K
CINDAS

FIGURE 7

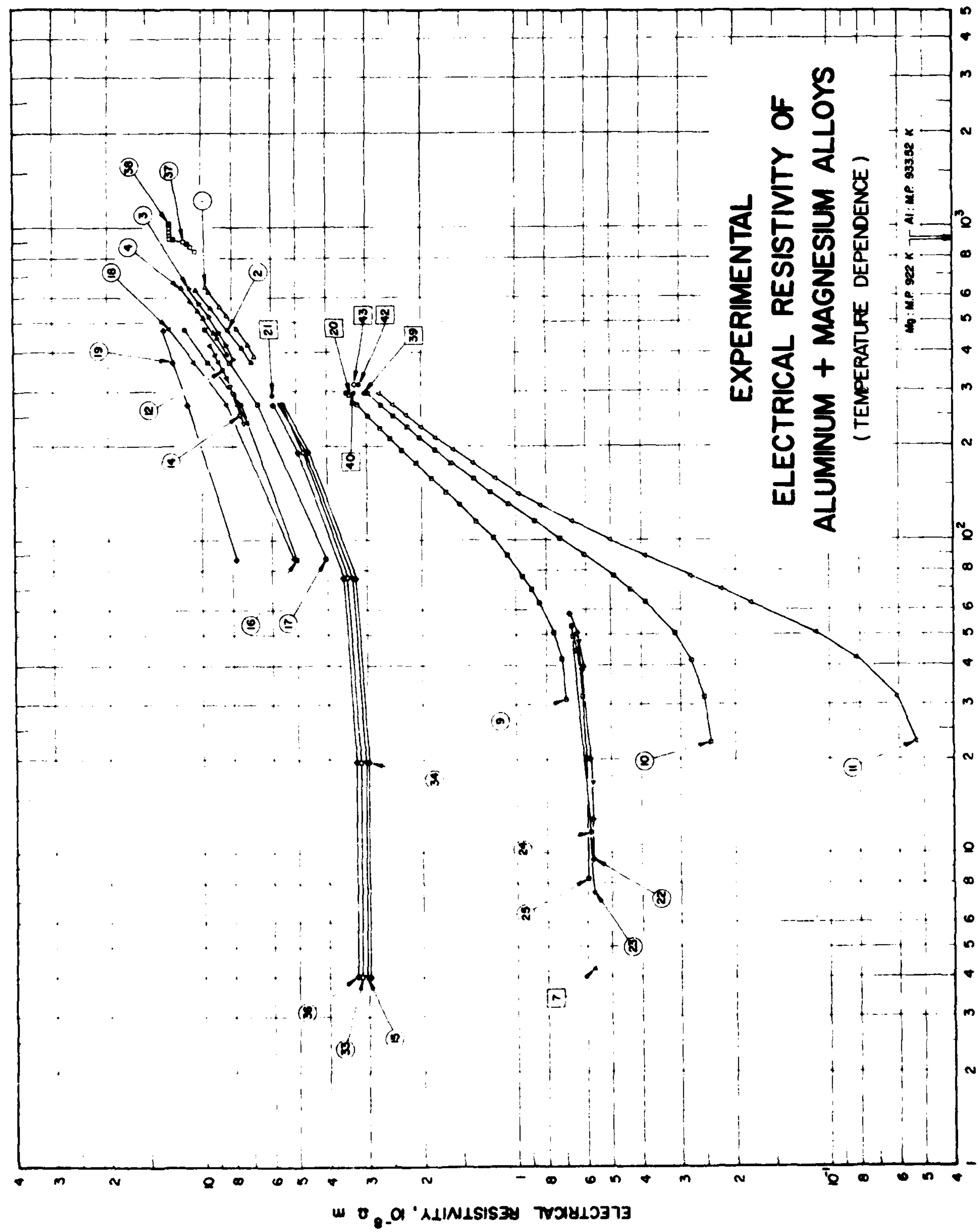
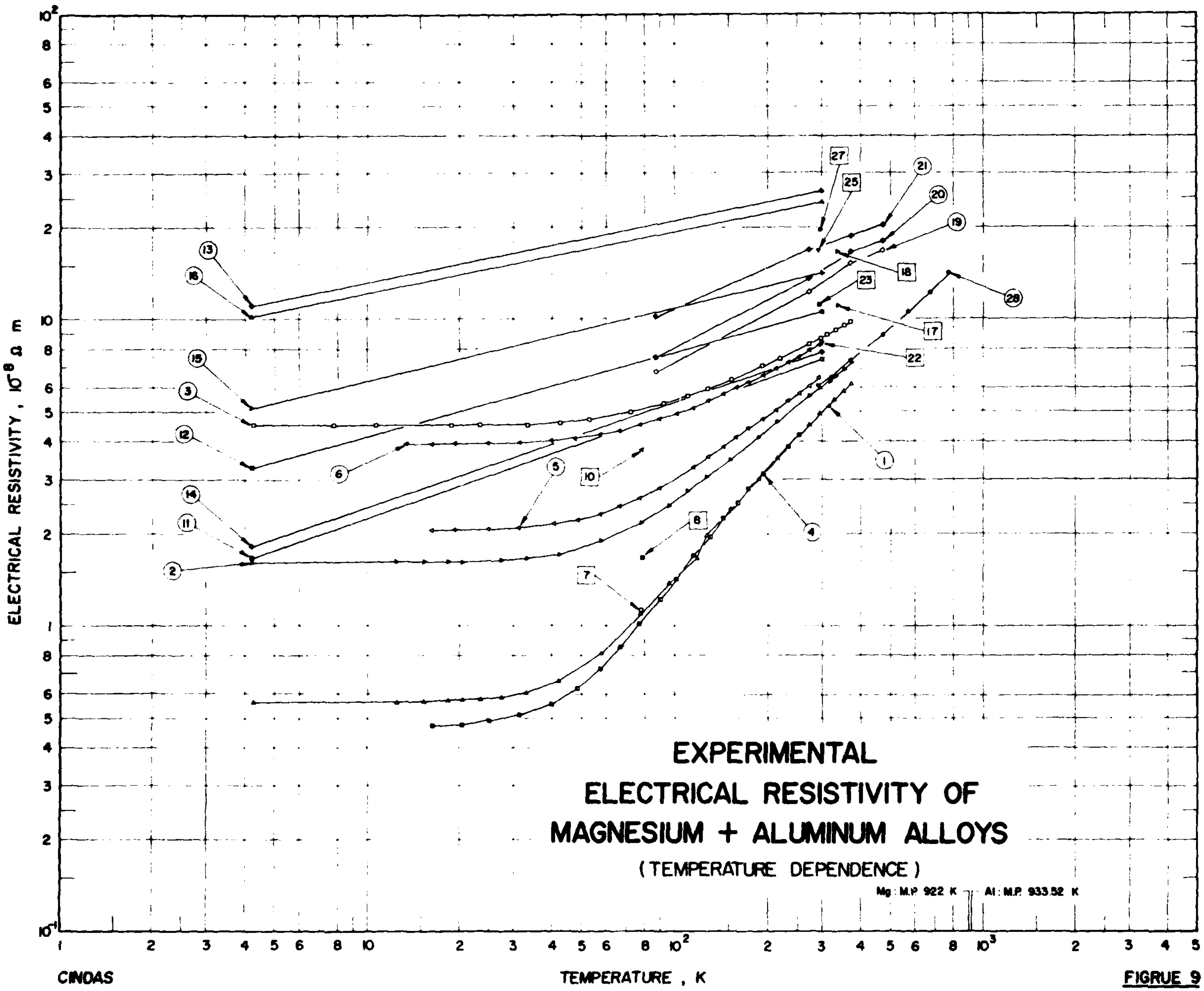

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
ALUMINUM + MAGNESIUM ALLOYS
(TEMPERATURE DEPENDENCE)
Mg: M.P. 922 K
Al: M.P. 933.52 K
TEMPERATURE , K
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
CINDAS

FIGURE 8


EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
MAGNESIUM + ALUMINUM ALLOYS
(TEMPERATURE DEPENDENCE)
Mg: M.P. 922 K
Al: M.P. 933.52 K
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE, K
CINDAS

FIGRUE 9

TABLE 9. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF ALUMINUM + MAGNESIUM ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Al	Mg	Composition (continued), Specifications, and Remarks
1	99	Hase, R., Heierberg, R., and Walkenhost, W.	1940	V	387-650	Hydronalium 5		5	Nominal composition; 6 to 10 mm in diameter and 25 cm long; cast at 973 K into molds at 473 K; rolled and drawn, then turned into rods.
2	99	Hase, R., et al.	1940	V	374-638	Hy 51			Similar to the above specimen except containing some Si as impurity.
3	99	Hase, R., et al.	1940	V	384-641	Hy 7		7	Nominal composition; same dimensions and fabrication method as the specimen for data set No. 1.
4	99	Hase, R., et al.	1940	V	396-643	Hy 71			Similar to the above specimen except containing some Si as impurity.
5*	108	Doyama, M., Koehler, J.S., Lwin, Y.N., Ryan, E.A., and Shaw, D.G.	1971	A	4.2	LD_2		0.08	Wires 0.127 mm in diameter drawn from 1.016 mm diameter wire supplied by Cominco (nominally 99.9999 aluminum and dopants); etched with a hot mixture of 95% phosphoric acid and 5% nitric acid between drawings; annealed in air; suddenly heated to 723 K and furnace cooled to room temperature.
6*	108	Doyama, M., et al.	1971	A	4.2	B1		0.1	Similar to the above specimen.
7	108	Doyama, M., et al.	1971	A	4.2	22		1.5	Similar to the above specimen.
8*	108	Doyama, M., et al.	1971	A	4.2	61		0.03	Similar to the above specimen.
9	101	Seth, R.S. and Woods, S.B.	1970	A	31-297			1.580	Calculated composition (1.75 a/o Mg); made by melting freshly cleaned pellets of silver and cadmium in sealed quartz tube of about 10 torr of hydrogen gas, homogenized by shaking periodically during a melt period lasting several h, then annealed just below the solidification temperature for several more h, about 6 mm diameter rod reduced to 1.5 mm by drawing through steel dies and reduced to 0.5 mm by drawing through diamond dies; annealed at 500 C for 12 h in a vacuum of 10^{-6} torr.
10	101	Seth, R.S. and Woods, S.B.	1970	A	23-298			0.550	Calculated composition (0.61 a/o Mg); similar to the above specimen.
11	101	Seth, R.S. and Woods, S.B.	1970	A	23-297			0.117	Calculated composition (0.13 a/o Mg); similar to the above specimen.
12	100	Cordier, H. and Detert, K.	1961	A	238-425			10.0	<0.01 each of Cu, Fe, and Si; polycrystalline; hot-pressed 12 mm thick rod cold-hammered to 5 mm thick, then cold-drawn to 2 mm or 0.5 mm thick, homogenized at 693 K and cooled slowly in air.
13*	100	Cordier, H. and Detert, K.	1961	A	238,293				Similar to the above except aged at 293 K.
14	100	Cordier, H. and Detert, K.	1961	A	238-314				Similar to the above except quenched from 1273 K.
15	102	Clark, A.F., Childs, G.E., and Wallace, G.H.	1969	A	4-273	Al 5083	94	4.75	0.63 Mn, 0.19 Fe, 0.13 Cr, the rest Cu, Ni, Si, Ti, V, and Zn; average grain size 0.077 mm.
16	79	Mannchen, W.	1931	V	87-476		92.0	8.0	Cast.
17	79	Mannchen, W.	1931	V	87-476		92.0	8.0	Annealed.
18	79	Mannchen, W.	1931	V	87-476		88.0	12.0	Cast.
19	79	Mannchen, W.	1931	V	87-476		86.0	14.0	Annealed.

* Not shown in figure.

TABLE 9. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF ALUMINUM + MAGNESIUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Al	Mg	Composition (continued), Specifications, and Remarks
20	109	Materials in Design Engineering	1959		293.2	5005		0.8	Nominal composition; annealed at 617 K.
21	109	Materials in Design Engineering	1959		293.2	5056		4.7 ~ 5.6	0.05-0.20 Cr and 0.05 ~ 0.20 Mn (nominal composition); annealed at 617 K.
22	110	Täubert, P., Thom, F., and Gammert, U.	1973		9.5-58	AlMg 1			Composition not reported; 1 mm diameter x 8 cm long; homogenized at 450 C for 4.5 h, then quenched in ice water.
23	110	Täubert, P., et al.	1973		7.4-47	AlMg 1			The above specimen; second run.
24	110	Täubert, P., et al.	1973		12, 54	AlMg 1			The above specimen reannealed at 30 C for 20 h and at 50 C for 20 h.
25	110	Täubert, P., et al.	1973		8.2-49	AlMg 1			The above specimen reannealed at 70 C for 20 h and at 70 C for 40 h.
26*	103	Clark, A. F., Childs, G. E., and Wallace, G. H.	1970	A	4.0-273	Al 5083	~94	4.75	0.63 Mn, 0.19 Fe, 0.13 Cr, and < 0.1 each of Cu, Ni, Si, Ti, V, and Zn; 6.35 mm diameter x 152 mm long; machined and heat-treated (H113); grain size 0.02 mm; measured across grain; reported error ~1%.
27*	103	Clark, A. F., et al.	1970	A	4.0-273	Al 5083			The above specimen measured with grain.
28*	104	Clark, A. F. and Tryon, P. V.	1972	A	4.0-273	5056		4.95	0.11 Fe, 0.09 Mn, 0.08 Si, 0.04 Zn, 0.02 Cu, 0.01 Ni, and 0.01 Ti; 0.635 cm diameter x 15.2 cm long; machined and ground; as received.
29*	104	Clark, A. F. and Tryon, P. V.	1972	A	4.0-273	5056			From the same heat as the above specimen.
30*	104	Clark, A. F. and Tryon, P. V.	1972	A	4.0-273	5056			From the same heat as the above specimen.
31*	104	Clark, A. F. and Tryon, P. V.	1972	A	4.0-273	5056			From the same heat as the above specimen.
32*	104	Clark, A. F. and Tryon, P. V.	1972	A	4.0-273	5056		4.93	0.12 Fe, 0.09 Mn, 0.08 Si, 0.03 Zn, 0.02 Cu, 0.01 Ni, and 0.01 Ti; 0.635 cm diameter x 15.2 cm long; from a *different* heat of the same manufacturer of the above specimen; as received.
33	104	Clark, A. F. and Tryon, P. V.	1972	A	4.0-273	5056		5.17	0.14 Fe, 0.10 Si, 0.09 Mn, 0.03 Cu, and 0.01 each of Ni, Ti, and Zn; similar to the above specimen except from another heat of the same manufacturer.
34	104	Clark, A. F. and Tryon, P. V.	1972	A	4.0-273	5056		4.94	0.12 Fe, 0.10 Mn, 0.09 Si, and 0.01 each of Cu, Ni, and Ti; similar to the above specimen except from another heat of the same manufacturer.
35*	104	Clark, A. F. and Tryon, P. V.	1972	A	4.0-273	5083		5	Nominal composition; 0.635 cm diameter x 15.2 cm long; from a different manufacturer of the above specimen; machined and ground; as received.
36	104	Clark, A. F. and Tryon, P. V.	1972	A	4.0-273	5083		5	Similar to the above specimen except from another manufacturer.
37	111	Romanov, O. V. and Persion, Z. V.	1973		843-1008	3		1.00	Calculated composition (1.11 a/o Mg); in solid and liquid states.
38	111	Romanov, O. V. and Persion, Z. V.	1973		893-1036	4		0.50	Calculated composition (0.56 a/o Mg); in solid and liquid states.
39	85	Robinson, A. T. and Dorn, J. E.	1951	B	297.2			0.499	Calculated composition (0.554 a/o Mg); impurities: 0.007 Cu, 0.003 Fe, and 0.003 Si; sheet specimen 0.070 in. thick and 0.250 in. wide; reported error ±0.5%.

* Not shown in figure.

TABLE 9. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF ALUMINUM + MAGNESIUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Al	Mg	Composition (continued), Specifications, and Remarks
40	85	Robinson, A. T. and Dorn, J. E.	1951	B	297.2			0.990	Calculated composition (1.097 a/o Mg); impurities: 0.007 Cu, 0.004 Fe, and 0.004 Si; sheet specimen 0.070 in. thick and 0.250 in. wide.
41*	85	Robinson, A. T. and Dorn, J. E.	1951	B	297.2			1.459	Calculated composition (1.617 a/o Mg); impurities: 0.006 Cu, 0.004 Fe, and 0.003 Si; sheet specimen 0.070 in. thick and 0.250 in. wide.
42	112	Rapp, Ö. and Fogelholm, R.	1974		318.2			0.24	Calculated composition (0.27 a/o Mg); $d\rho/dT = 0.0114\ \mu\Omega\ cm\ K^{-1}$ at 318.2 K.
43	112	Rapp, Ö. and Fogelholm, R.	1974		318.2			0.43	Calculated composition (0.48 a/o Mg); $d\rho/dT = 0.0114\ \mu\Omega\ cm\ K^{-1}$ at 318.2 K.

* Not shown in figure.

TABLE 10. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF ALUMINUM + MAGNESIUM ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

DATA SET 1

T	ρ
387	6.80
423	7.13
475	7.70
525	8.30
560	8.70
575	8.90*
625	9.45
650	9.70

DATA SET 2

T	ρ
374.5	6.95
377.3	6.99*
412.3	7.46
472.8	8.26
553.4	9.34
637.8	10.47

DATA SET 3

T	ρ
393.8	7.92
426.4	8.35
462.1	8.83
521.1	9.43
573.5	10.11
588.6	10.26*
641.2	10.81

DATA SET 4

T	ρ
396.3	8.32
446.1	8.93
462.3	9.14
513.5	9.85
544.7	10.33
585.3	10.83
643.2	11.52

DATA SET 5*

T	ρ
4.2	0.03748

DATA SET 6*

T	ρ
4.2	0.03457

DATA SET 7

T	ρ
4.2	0.56507

DATA SET 8*

T	ρ
4.2	0.00943

DATA SET 9

T	ρ
31.2	0.695
42.0	0.720
51.0	0.765
63.5	0.844
69.8	0.891
77.0	0.955
89.3	1.077
101.2	1.194
115.7	1.354
130.4	1.527
143.0	1.680
158.7	1.864
176.5	2.078
195.6	2.301
214.7	2.525
230.8	2.711
252.3	2.964
273.2	3.207
297.0	3.480

DATA SET 10

T	ρ
22.6	0.240
31.8	0.251
41.7	0.277
50.9	0.314
63.1	0.386
69.8	0.433
76.7	0.489
89.4	0.610
101.0	0.726
115.4	0.878
130.1	1.052
143.1	1.202
158.4	1.374
176.9	1.601
195.4	1.814
214.6	2.035

DATA SET 10 (cont.)

T	ρ
231.3	2.220
252.3	2.465
272.6	2.696
297.6	2.976

DATA SET 11

T	ρ
22.8	0.053
31.5	0.061
42.0	0.082
50.8	0.111
63.2	0.179
69.8	0.221
76.7	0.279
88.4	0.388
100.5	0.500
115.3	0.665
129.9	0.831
142.9	0.986
158.3	1.166
176.4	1.376
195.0	1.594
214.0	1.806
230.9	2.001
251.9	2.241
272.7	2.465
296.7	2.746

DATA SET 12

T	ρ
238.2	7.20
273.2	7.61
293.2	7.86
333.2	8.34
353.2	8.58
373.2	8.83
393.2	9.06
424.7	9.42

DATA SET 13*

T	ρ
238.4	7.25
293.4	7.91

DATA SET 14

T	ρ
237.8	7.34
252.7	7.52
273.2	7.73*
297.5	7.97
302.8	8.02*
308.1	8.07*
313.5	8.12

DATA SET 15

T	ρ
4.0	3.030
19.65	3.032
75.75	3.319
192.4	4.694
273	5.658

DATA SET 16

T	ρ
87	5.00
273	7.57
373	9.52
476	11.36

DATA SET 17

T	ρ
87	4.08
273	6.64
373	8.16
476	9.76

DATA SET 18

T	ρ
87	5.10
273	8.37
373	10.64
476	12.74

DATA SET 19

T	ρ
87	7.87
273	11.16
373	12.42
476	13.16

DATA SET 20

T	ρ
293.2	3.4

DATA SET 21

T	ρ
293.2	5.94

DATA SET 22

T	ρ
9.5	0.574
12.8	0.575
13.2	0.578*
20.1	0.584
58.1	0.680

DATA SET 23

T	ρ
7.4	0.572
16.9	0.579
47.2	0.637

DATA SET 24

T	ρ
11.6	0.583
53.5	0.669

DATA SET 25

T	ρ
8.2	0.592
20.1	0.596
31.6	0.618
44.7	0.641
49.3	0.666

DATA SET 26*

T	ρ
4.0	3.065
19.65	3.069
75.75	3.362
192.4	4.741
273	5.711

DATA SET 27*

T	ρ
4.0	3.052
19.65	3.054
75.75	3.344

DATA SET 27 (cont.)*

T	ρ
192.4	4.715
273	5.683

DATA SET 28*

T	ρ
4.0	3.076
19.65	3.080
75.75	3.362
192.4	4.697
273.2	5.644

DATA SET 29*

T	ρ
4.0	3.074
19.65	3.077
75.75	3.360
192.4	4.697
273.2	5.649

DATA SET 30*

T	ρ
4.0	3.074
19.65	3.074
75.75	3.357
192.4	4.699
273.2	5.641

DATA SET 31*

T	ρ
4.0	3.057
19.65	3.060
75.75	3.342
192.4	4.679
273.2	5.617

DATA SET 32*

T	ρ
4.0	3.085
19.65	3.087
75.75	3.370
192.4	4.722
273.2	5.662

* Not shown in figure.

TABLE 10. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF ALUMINUM + MAGNESIUM ALLOYS (Temperature Dependence) (continued)

DATA SET 33

T	ρ
4.0	3.152
19.65	3.168
75.75	3.455
192.4	4.729
273.2	5.690*

DATA SET 34

T	ρ
4.0	2.999
19.65	3.002
75.75	3.285
192.4	4.642
273.2	5.502

DATA SET 35*

T	ρ
4.0	3.003
19.65	3.007
75.75	3.288
192.4	4.640
273.2	5.501

DATA SET 36

T	ρ
4.0	3.261
19.65	3.264
75.75	3.556
192.4	4.946
273.2	5.918

DATA SET 37

T	ρ
843	10.55
872	10.93
896	11.12*
906	11.47
927	27.40
948	27.40
969	27.62*
977	27.62
1006	27.86

DATA SET 38

T	ρ
893	11.27
920	12.24
931	26.60*
940	26.60*

DATA SET 38 (cont.)

T	ρ
966	26.60*
989	26.67*
1036	27.40

DATA SET 39

T	ρ
297.2	3.030

DATA SET 40

T	ρ
297.2	3.296

DATA SET 41*

T	ρ
297.2	3.520

DATA SET 42

T	ρ
318.2	3.19

DATA SET 43

T	ρ
318.2	3.29

* Not shown in figure.

TABLE 11. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF MAGNESIUM + ALUMINUM ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Mg	Al	Composition (continued), Specifications, and Remarks
1	107	Hedgcock, F.T. and Muri, W.B.	1964	A	4.2-373	400		0.32	Calculated composition (0.29 a/o Al); 4 x 0.125 x 0.01 in.; specimen cut from the supplied ingots, rolled into 0.01 in. strips, etched, cut to size; annealed in a helium atmosphere at 7 cm of Hg at 450 C for 12 h; electrical resistivity data calculated from the resistance ratio R(T)/R(273) reported by the author; electrical resistivity reported as 4.545 $\mu\Omega$cm at 273 K; reported error ±0.2%.
2	107	Hedgcock, F.T. and Muri, W.B.	1964	A	4.2-373	402		0.89	Calculated composition (0.80 a/o Al); similar to the above specimen except electrical resistivity reported as 5.624 $\mu\Omega$ cm at 273 K.
3	107	Hedgcock, F.T. and Muri, W.B.	1964	A	4.3-373	405		2.67	Calculated composition (2.41 a/o Al); similar to the above specimen except electrical resistivity reported as 8.333 $\mu\Omega$ cm at 273 K.
4	101	Seth, R.S. and Woods, S.B.	1970	A	16-295			0.24	Calculated composition (0.22 a/o Al); 99.98+ pure; prepared by Dow Chemical Co. from sublimed magnesium; obtained in the form of a non-uniform 0.035 in. diameter wire, drawn through the 0.032 in. diamond die to produce uniform, smooth wires; annealed at 350 C for 8 h in a hydrogen gas.
5	101	Seth, R.S. and Woods, S.B.	1970	A	16-294			1.10	Calculated composition (0.98 a/o Al); similar to the above specimen.
6	101	Seth, R.S. and Woods, S.B.	1970	A	13-294			2.10	Calculated composition (1.90 a/o Al); similar to the above specimen.
7	113	Blatt, F.J.	1968		78			0.32	No details reported.
8	113	Blatt, F.J.	1968		78			0.59	No details reported.
9*	113	Blatt, F.J.	1968		78			0.89	No details reported.
10	113	Blatt, F.J.	1968		78			1.82	No details reported.
11	114	Collings, E.W., Hedgcock, F.T., Muir, W.B., and Muto, Y.	1964		4.2,300	402		0.90	No details reported.
12	114	Collings, E.W., et al.	1964		4.2,300	403		1.84	No details reported.
13	114	Collings, E.W., et al.	1964		4.2,300	407		6.10	No details reported.
14	114	Collings, E.W., et al.	1964		4.2,300	91076		1.03	0.061 Mn.
15	114	Collings, E.W., et al.	1964		4.2,300	91077		2.87	0.056 Mn.
16	114	Collings, E.W., et al.	1964		4.2,300	91078		5.51	0.050 Mn.
17	55	Smith, A.W.	1925	B	336.2		95.82	4.12	0.028 Fe and 0.019 Si; supplied by Aluminum Co. of America.
18	55	Smith, A.W.	1925	B	336.2		89.82	10.12	0.023 Si and 0.028 Fe; supplied by Aluminum Co. of America.
19	105, 79	Staebler, J.; Mannchen, W.	1929	V	87-476		94.0	6.0	Cast.
20	105, 79	Staebler, J.; Mannchen, W.	1929	V	87-476		92.0	8.0	Cast.

* Not shown in figure.

TABLE 11. MEASUREMENT INFORMATION ON THE *ELECTRICAL RESISTIVITY* OF MAGNESIUM + ALUMINUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Mg	Al	Composition (continued), Specifications, and Remarks
21	105, 79	Staebler, J.; Hannchen, W.	1929	V	87-476		88	12	Cast.
22	115	Kikuchi, R.	1932		300.2		97.9	2.1	No details reported.
23	115	Kikuchi, R.	1932		295.5		95.8	4.2	No details reported.
24*	115	Kikuchi, R.	1932		295.1		93.8	6.2	No details reported.
25	115	Kikuchi, R.	1932		295.1		91.8	8.2	No details reported.
26*	115	Kikuchi, R.	1932		292.5		89.7	10.3	No details reported.
27	115	Kikuchi, R.	1932		293.6		87.8	12.2	No details reported.
28	106	Powell, R.W., Hickman, M.J., and Tye, R.P.	1964		293-773	Magnox B		1.0	0.002 to 0.003 Be; 2.5 cm diameter x 20* cm long.

* Not shown in figure.

TABLE 12. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF MAGNESIUM + ALUMINUM ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ωm]

DATA SET 1

T	ρ
4.24	0.564
12.47	0.564
15.24	0.567*
18.38	0.571
20.38	0.573*
23.3	0.578
27.1	0.588*
33.0	0.609
42.0	0.662
57.9	0.814
77.9	1.100
95.3	1.395
110.8	1.673
127.8	1.986
151.3	2.413
186.8	3.0[illegible]
215.5	3.5[illegible]
273.1	4.545
295.9	4.922
316.1	5.240
320.4	5.322*
331.8	5.490
352.2	5.840
372.7	6.172

DATA SET 2

T	ρ
4.24	1.625
12.47	1.631
15.24	1.631
18.38	1.637*
20.38	1.637
23.3	1.642*
27.1	1.653
33.0	1.682
42.0	1.738
57.9	1.901
77.9	2.188
95.3	2.486
110.8	2.773
127.8	3.088
151.3	3.487
186.8	4.122
215.5	4.623
273.1	5.624
295.9	5.984

DATA SET 2 (cont.)

T	ρ
316.1	6.305
320.4	6.383*
331.8	6.563
352.2	6.887
372.7	7.238

DATA SET 3

T	ρ
4.28	4.533
7.72	4.533*
10.61	4.533
12.37	4.533*
15.30	4.533*
18.71	4.533
20.74	4.541*
23.4	4.550
27.3	4.558*
33.3	4.583
42.5	4.641
53.0	4.741
72.3	5.008
77.8	5.091*
92.8	5.341
110.8	5.658
129.7	5.975
153.7	6.391
191.4	7.025
220.0	7.483
273.1	8.333
298.2	8.700
314.8	8.950
334.0	9.241
355.2	9.575
372.7	9.825

DATA SET 4

T	ρ
16.2	0.475
20.1	0.479
24.8	0.490
31.2	0.511
39.7	0.559
48.1	0.628
57.2	0.726
66.6	0.8[illegible]
76.7	1.[illegible]

DATA SET 4 (cont.)

T	ρ
89.6	1.232
101.8	1.448
115.9	1.708
130.0	1.977
144.6	2.261
160.1	2.541
174.8	2.823
194.3	3.152
214.6	3.526*
234.5	3.872
253.7	4.217
273.0	4.553*
294.7	4.929*

DATA SET 5

T	ρ
16.2	2.062
19.3	2.076
24.7	2.078
31.1	2.101
40.2	2.152
48.3	2.229
57.2	2.333
66.9	2.473
77.0	2.631
89.2	2.834
115.3	3.301
129.6	3.575
144.4	3.857
159.7	4.139
174.5	4.421
194.2	4.740
214.2	5.089
233.6	5.428
252.2	5.752
273.1	6.117
294.2	6.444

DATA SET 6

T	ρ
13.4	3.954
16.2	3.957
19.3	3.961
24.7	3.974
31.1	3.997
39.8	4.051

DATA SET 6 (cont.)

T	ρ
47.6	4.117
57.2	4.233
66.6	4.369
77.1	4.531
89.5	4.740
101.5	4.931
115.2	5.190
129.6	5.457
144.9	5.733
159.3	6.000
174.4	6.275
193.7	6.597
213.6	6.930
234.2	7.275
253.0	7.596
272.9	7.930
294.2	8.277

DATA SET 7

T	ρ
78	1.132

DATA SET 8

T	ρ
78	1.683

DATA SET 9*

T	ρ
78	2.191

DATA SET 10

T	ρ
78	3.788

DATA SET 11

T	ρ
4.2	1.670
300	7.449

DATA SET 12

T	ρ
4.2	3.307
300	10.69

DATA SET 13

T	ρ
4.2	11.28
300	26.40

DATA SET 14

T	ρ
4.2	1.845
300	7.874

DATA SET 15

T	ρ
4.2	5.140
300	14.19

DATA SET 16

T	ρ
4.2	10.21
300	24.08

DATA SET 17

T	ρ
336.2	11.04

DATA SET 18

T	ρ
336.2	16.67

DATA SET 19

T	ρ
87	6.80
273	12.44
373	15.46
476	16.69

DATA SET 20

T	ρ
87	7.51
273	13.68
373	16.81
476	18.02

DATA SET 21

T	ρ
87	10.36
273	16.69
373	18.98
476	20.41

DATA SET 22

T	ρ
300.2	8.49

DATA SET 23

T	ρ
295.5	11.24

DATA SET 24*

T	ρ
295.1	14.49

DATA SET 25

T	ρ
291.5	16.95

DATA SET 26*

T	ρ
292.5	18.18

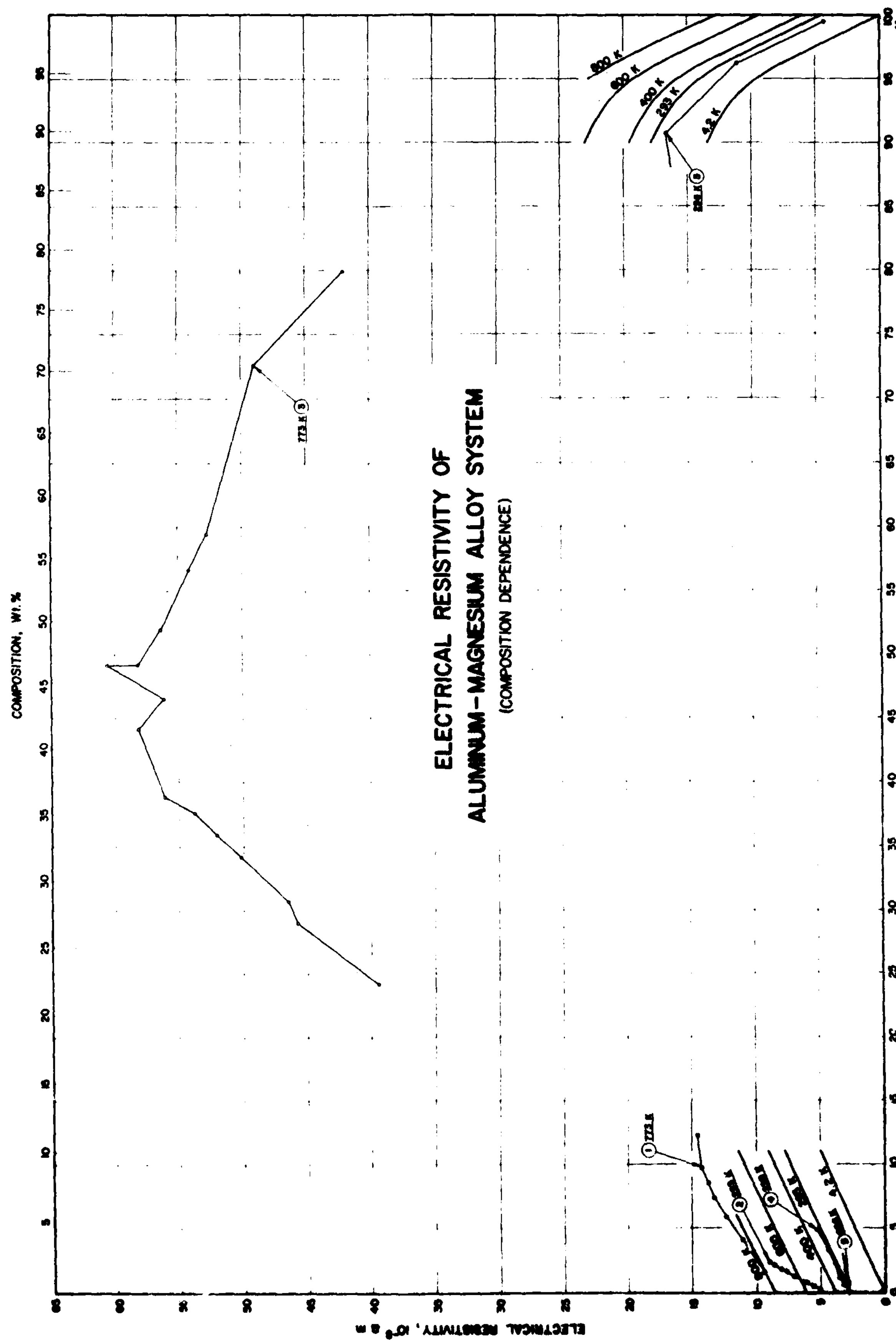
DATA SET 27

T	ρ
296.3	19.60

DATA SET 28

T	ρ
293	6.05
323	6.5
373	7.3
473	8.9
573	10.6
673	12.3
773	14.15

* Not shown in figure.



ELECTRICAL RESISTIVITY OF
ALUMINUM-MAGNESIUM ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION, Wt. %
COMPOSITION, At. %
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
800 K
600 K
400 K
293 K
4.2 K
773 K
Al
Mg

FIGURE 10

TABLE 13. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF ALUMINUM-MAGNESIUM ALLOY SYSTEM (Composition Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Mg)	Composition (weight percent), Specifications, and Remarks
1	116	Matsuda, T. and Sato, T.	1966	A	773.2	1.5-12	50 x 3 x 2 mm; prepared from 99.999 Al and 99.99 Mg by melting in an induction furnace; homogenized in vacuum, cut and rolled.
2	117	Salkovitz, E.I., Schindler, A.I., and Kammer, E.W.	1957	B	293.2	0.3-2.4	Polycrystallines; specimens 9.54 to 29.30 cm long, 0.412 to 0.640 cm wide, and 0.212 to 0.240 cm thick; extruded and annealed; $d\rho/dT$ ranging from 1.605 to 1.494×10^{-2} $\mu\Omega$ cm C^{-1} at room temperature.
3	118	Steeb, S. and Wörner, S.	1965		773.2	24-80	Alloys in liquid state.
4	62	Gulyaev, A.P. and Trusova, E.F.	1950		293.2	0.6-4.9	Measuring temperature assigned here as 20 C.
5	55	Smith, A.W.	1925	B	296.2	0-100	Specimens about 0.3 cm^2 in cross-section and 5 cm long; supplied by Aluminum Co. of America.

TABLE 14. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF ALUMINUM-MAGNESIUM ALLOY SYSTEM (Composition Dependence)

[Composition, C, a/o Mg; Electrical Resistivity, ρ, 10^{-8} Ω m]

C	ρ	C	ρ
DATA SET 1 (T = 773.2 K)		DATA SET 4 (T = 293.2 K)	
1.54	9.40	0.57	3.19
4.02	11.05	1.14	3.505
5.91	12.35	2.2	3.86
7.41	13.22	3.27	4.315
8.51	13.72	4.89	5.24
9.70	14.23	DATA SET 5 (T = 296.2 K)	
12.29	14.54		
DATA SET 2 (T = 293.2 K)		0	2.73
		90.73	16.67
0.29	5.032	96.22	11.04
0.53	5.538	99.95	4.26
0.80	6.091		
0.88	6.216		
1.31	7.036		
1.64	7.688		
1.82	8.081		
2.18	8.646		
2.41	9.064		
DATA SET 3 (T = 773.2 K)			
24.1	39.5		
28.9	45.8		
30.6	46.5		
34.1	50.2		
35.8	52.1		
37.5	53.8		
38.8	56.2		
44.1	58.2		
46.5	56.2		
49.1	60.6		
49.1	58.2		
51.9	56.4		
56.6	54.2		
59.4	52.8		
72.5	49.0		
79.9	42.0		

3.3. Copper-Gold Alloy System

The copper-gold alloy system forms a continuous series of solid solutions over the entire range of compositions. However, ordered structures are formed at temperatures below 663 K for compositions ranging from about 40 to 63% Au (17.7 to 35.5 at.% Au) and below 683 K for compositions ranging from about 63 to 94% Au (35.5 to 83.5 at.% Au). These ordered structures are due to the formation of intermetallic compounds Cu_3Au (50.85% Au), CuAu (75.63% Au), and $CuAu_3$ (90.30% Au). For Cu_3Au and CuAu, the ordered state possesses a remarkably lower resistivity than that of the disordered state. However, for $CuAu_3$ it has been found that the electrical resistivity increases as ordering proceeds below the transition point, but the residual resistivity is slightly lower in the highly ordered state [119-121].

The experiments by Johansson and Linde [122] (Cu-Au data sets 1-3) showed the dependence of the electrical resistivity on the degree of ordering. Solid solutions of metals are usually of the substitutional type in which the different atoms are positioned randomly at sites of the crystal lattice. In a number of alloys with stoichiometric composition and at sufficiently low temperatures, the atoms are arranged in such a manner that each species of atom occupies only a certain type of site in the crystal lattice; an alloy in this state is called ordered. As the temperature increases, there is a transition of some of the atoms from their sites to foreign sites; such an alloy is called partially ordered. The concentration of atoms of a given type on foreign sites increases with temperature and at some temperature the concentration of atoms on sites of different types becomes identical; such an alloy is called disordered. The temperature at which such a transition occurs is called the order-disorder phase transition temperature or the critical temperature. The order-disorder phase transition occurs not only in alloys with stoichiometric composition and the critical temperature is a well defined function of composition. In this work experimental data on intermetallic compounds and ordered alloys are excluded, though data on partially ordered alloys are compiled and presented in the figures and tables. However, these data are not evaluated or analyzed since recommended values for disordered alloys only are generated.

There are 243 sets of experimental data available for this alloy system. These experimental data sets are listed in tables 16, 18, and 20, tabulated in

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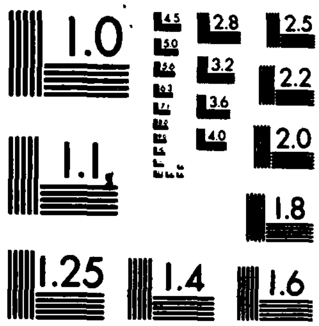

1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

tables 17, 19, and 21 , and shown partially in figures 13, 14, and 15. Unfortunately, most of the available data are for specimens in partially ordered state. For the disordered state, more important experimental data and information are from the following. Johansson and Linde [122] (Cu-Au data sets 1-3) reported a complete curve of resistivity versus composition at 293 K. Borelius, Johansson, and Linde [123] (Cu + Au data sets 6-8 and Au + Cu data sets 1-22) measured a series of alloys containing 20.2, 22.6, 25.0, 27.7, 30.1, 45.0, 50.0, and 55.0 at.% Au during both heating and cooling of the specimens. Passaglia and Love [124] (Au + Cu data sets 23-26) measured the resistivity of Au + Cu alloys from liquid helium temperature to about 90 K for both quenched and annealed specimens. Tainsh and White [125] (Cu + Au data sets 9, 10) reported the resistivity of alloys containing 20.1 and 38.0 wt.% Au at 4.2, 90, and 293 K. Linde [126] (Cu + Au data sets 1-5) reported the resistivity at 291.2 K of alloys containing 1.53, 3.00, 5.92, 7.05, and 8.75 wt.% Au.

The smoothing and synthesizing of the electrical resistivity data was based mainly on the results reported in the above five research papers. Since Cu, Ag, and Au are in the same column of the periodic table, the properties of Au + Cu alloys and Au + Ag alloys may be similar in some respects. Accordingly, in the composition range where ordering occurs, some of the resistivity versus temperature curves have been obtained by taking a point on the resistivity versus composition isotherm and drawing a curve parallel to the electrical resistivity curve of an Au + Ag alloy of the same atomic concentration; values obtained in this way for the electrical resistivity are considered only provisional. Using this method, the values obtained for the gold-rich alloys would appear to be more reliable than those for the copper-rich alloys.

The resulting recommended electrical resistivity values for Cu, Au, and for 25 Cu-Au binary alloys are presented in table 15 and shown in figures 11, 12, and 15. The recommended values for Cu and for Au are for well-annealed high-purity specimens, but those values for temperatures below about 100 K are applicable only to Cu and Au having residual electrical resistivities as given at 1 K in table 15. The alloys for which the recommended values are generated are not ordered and have not been quenched or cold-worked severely. The recommended values cover a full range of temperature from 1 K to the solidus temperature of the alloy where melting starts. These values are not corrected for the thermal expansion of the material. The estimated uncertainties in

the values for the various alloys and for different temperature ranges are explicitly stated in a footnote to table 15. Many of the values in table 15 are indicated as provisional because their uncertainties are greater than ±5%.

TABLE 15. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-GOLD ALLOY SYSTEM†

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Cu: 100.00% (100.00 At.%) Au: 0.00% (0.00 At.%)		Cu: 99.50% (99.84 At.%) Au: 0.50% (0.16 At.%)		Cu: 99.00% (99.68 At.%) Au: 1.00% (0.32 At.%)		Cu: 97.00% (99.01 At.%) Au: 3.00% (0.99 At.%)		Cu: 95.00% (98.33 At.%) Au: 5.00% (1.67 At.%)		Cu: 90.00% (96.54 At.%) Au: 10.00% (3.46 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	0.00200	1	0.100*‡	1	0.200*‡	1	0.530*‡	1	0.870*‡	1	1.72*‡
4	0.00200	4	0.100‡	4	0.200‡	4	0.530*‡	4	0.870‡	4	1.72*‡
7	0.00200	7	0.100*‡	7	0.200*‡	7	0.530*‡	7	0.870*‡	7	1.72*‡
10	0.00202	10	0.100*‡	10	0.200*‡	10	0.530*‡	10	0.870*‡	10	1.72*‡
15	0.00218	15	0.100*‡	15	0.200*‡	15	0.530*‡	15	0.870*‡	15	1.72*‡
20	0.00280	20	0.100*‡	20	0.200*‡	20	0.530*‡	20	0.870*‡	20	1.72*‡
25	0.00450	25	0.102*‡	25	0.200*‡	25	0.530*‡	25	0.870*‡	25	1.72*‡
30	0.00530	30	0.108*‡	30	0.201*‡	30	0.531*‡	30	0.871*‡	30	1.73*‡
40	0.0240	40	0.120*‡	40	0.210*‡	40	0.540*‡	40	0.879*‡	40	1.75*‡
50	0.0520	50	0.141*‡	50	0.229*‡	50	0.559*‡	50	0.901*‡	50	1.78*‡
60	0.0974	60	0.180*‡	60	0.261*‡	60	0.591*‡	60	0.941*‡	60	1.84*‡
70	0.154	70	0.237*‡	70	0.311*‡	70	0.641*‡	70	0.997*‡	70	1.90*‡
80	0.216	80	0.302*‡	80	0.378*‡	80	0.709*‡	80	1.06*‡	80	1.96*‡
90	0.282	90	0.370*‡	90	0.450*‡	90	0.780*‡	90	1.14*‡	90	2.04*‡
100	0.349	100	0.439*‡	100	0.520*‡	100	0.850*‡	100	1.21*‡	100	2.11*‡
150	0.701	150	0.790*	150	0.871*	150	1.20*	150	1.56*	150	2.46*
200	1.048	200	1.14*	200	1.22*	200	1.56*	200	1.91*	200	2.50*
250	1.388	250	1.49*	250	1.57*	250	1.91*	250	2.25*	250	3.14*
273	1.544	273	1.64	273	1.73	273	2.06	273	2.41	273	3.29
293	1.678	293	1.77*	293	1.86*	293	2.20*	293	2.54*	293	3.42*
300	1.725	300	1.82*	300	1.91*	300	2.24*	300	2.59*	300	3.46*
350	2.061	350	2.14*	350	2.24*	350	2.58*	350	2.92*	350	3.79*
400	2.398	400	2.48*	400	2.58*	400	2.91*	400	3.26*	400	4.12*
500	3.079	500	3.17*‡	500	3.27*‡	500	3.60*‡	500	3.95*‡	500	4.81*‡
600	3.771	600	3.88*‡	600	3.98*‡	600	4.31*‡	600	4.66*‡	600	5.52*‡
700	4.481	700	4.58*‡	700	4.69*‡	700	5.01*‡	700	5.37*‡	700	6.22*‡
800	5.213	800	5.31*‡	800	5.42*‡	800	5.74*‡	800	6.10*‡	800	6.94*‡
900	5.973	900	6.06*‡	900	6.16*‡	900	6.50*‡	900	6.86*‡	900	7.69*‡
1000	6.766	1000	6.86*‡	1000	6.96*‡	1000	7.29*‡	1000	7.64*‡	1000	8.48*‡
1100	7.596	1100	7.69*‡	1100	7.80*‡	1100	8.11*‡	1100	8.46*‡	1100	9.30*‡
1200	8.470	1200	8.55*‡	1200	8.66*‡	1200	8.98*‡	1200	9.32*‡	1200	10.16*‡
1300	9.395	1300	9.41*‡	1300	9.52*‡	1300	9.85*‡	1300	10.18*‡	1300	11.02*‡
1357.6	9.946(s)	1355	9.88*‡	1353	9.96*‡	1346	10.25*‡	1339	10.53*‡	1320	11.19*‡
1358	21.01(ℓ)										
1700	24.41										

† Uncertainties in the electrical resistivity values are as follows:

100.00 Cu - 0.00 Au: ±3% up to 100 K, ±1% above 100 K to 250 K, ±0.5% above 250 K to 350 K, ±1% above 350 K to 500 K, ±4% above 500 K to 1357.6 K, and ±8% above 1357.6 K.
99.50 Cu - 0.50 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
99.00 Cu - 1.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
97.00 Cu - 3.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
95.00 Cu - 5.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
90.00 Cu - 10.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 18. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-GOLD ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Cu: 85.00% (94.61 At.%) Au: 15.00% (5.39 At.%)		Cu: 80.00% (92.54 At.%) Au: 20.00% (7.46 At.%)		Cu: 75.00% (90.29 At.%) Au: 25.00% (9.71 At.%)		Cu: 70.00% (87.85 At.%) Au: 30.00% (12.15 At.%)		Cu: 65.00% (85.20 At.%) Au: 35.00% (14.80 At.%)		Cu: 60.00% (82.30 At.%) Au: 40.00% (17.70 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	2.58*‡	1	3.52*‡	1	4.45*‡	1	5.47*‡	1	6.52*‡	1	7.52*‡
4	2.58‡	4	3.52‡	4	4.45‡	4	5.47‡	4	6.52‡	4	7.52‡
7	2.58*‡	7	3.52*‡	7	4.45*‡	7	5.47*‡	7	6.52*‡	7	7.52*‡
10	2.58*‡	10	3.52*‡	10	4.45*‡	10	5.47*‡	10	6.52*‡	10	7.52*‡
15	2.58*‡	15	3.52*‡	15	4.45*‡	15	5.48*‡	15	6.53*‡	15	7.53*‡
20	2.59*‡	20	3.52‡	20	4.45‡	20	5.49‡	20	6.54‡	20	7.54‡
25	2.60*‡	25	3.53‡	25	4.46‡	25	5.50‡	25	6.55*‡	25	7.56‡
30	2.61*‡	30	3.54‡	30	4.47‡	30	5.51‡	30	6.57*‡	30	7.59‡
40	2.63*‡	40	3.57‡	40	4.49‡	40	5.54‡	40	6.61*‡	40	7.66‡
50	2.68*‡	50	3.61‡	50	4.52‡	50	5.57‡	50	6.67*‡	50	7.72‡
60	2.73*‡	60	3.67‡	60	4.58‡	60	5.63‡	60	6.74*‡	60	7.78‡
70	2.80*‡	70	3.74‡	70	4.64‡	70	5.70‡	70	6.80‡	70	7.85‡
80	2.87*‡	80	3.80‡	80	4.72‡	80	5.77‡	80	6.87*‡	80	7.92‡
90	2.94*‡	90	3.88‡	90	4.79‡	90	5.84‡	90	6.93*‡	90	7.95‡
100	3.01*‡	100	3.95‡	100	4.86‡	100	5.91‡	100	7.00*‡	100	8.04‡
150	3.36*	150	4.30	150	5.22	150	6.26	150	7.33*	150	8.37
200	3.70*	200	4.65	200	5.59	200	6.62	200	7.66*	200	8.70
250	4.04*	250	4.99	250	5.93	250	6.96	250	8.00*	250	9.03
273	4.20	273	5.15	273	6.09	273	7.12	273	8.16	273	9.18
293	4.33	293	5.28	293	6.23	293	7.25	293	8.29	293	9.31
300	4.38*	300	5.32	300	6.28	300	7.30	300	8.34*	300	9.36
350	4.71*	350	5.65	350	6.63	350	7.64	350	8.69*	350	9.70
400	5.05*	400	5.99	400	6.98	400	7.99	400	9.04*	400	10.05
500	5.72*‡	500	6.68*‡	500	7.66‡	500	8.67‡	500	9.72*‡	500	10.75*‡
600	6.42*‡	600	7.37*‡	600	8.37‡	600	9.37‡	600	10.43*‡	600	11.47*‡
700	7.13*‡	700	8.09*‡	700	9.08‡	700	10.08‡	700	11.14*‡	700	12.19*‡
800	7.87*‡	800	8.82*‡	800	9.81‡	800	10.81‡	800	11.87*‡	800	12.93*‡
900	8.62*‡	900	9.55*‡	900	10.56‡	900	11.55‡	900	12.61*‡	900	13.69*‡
1000	9.39*‡	1000	10.30*‡	1000	11.32‡	1000	12.30*‡	1000	13.37*‡	1000	14.49*‡
1100	10.18*‡	1100	11.07*‡	1100	12.09‡	1100	13.08*‡	1100	14.15*‡	1100	15.31*‡
1200	11.00*‡	1200	11.86*‡	1200	12.88‡	1200	13.87*‡	1200	14.96*‡	1200	16.15*‡
1303	11.84*‡	1289	12.56*‡	1277	13.49‡	1265	14.38*‡	1255	15.41*‡	1245	16.53*‡

† Uncertainties in the electrical resistivity values are as follows:

85.00 Cu - 15.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
80.00 Cu - 20.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
75.00 Cu - 25.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
70.00 Cu - 30.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
65.00 Cu - 35.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
60.00 Cu - 40.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 15. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-GOLD ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega\ m$]

Cu: 55.00% (79.12 At.%) Au: 45.00% (20.88 At.%)		Cu: 50.00% (75.61 At.%) Au: 50.00% (24.39 At.%)		Cu: 45.00% (71.72 At.%) Au: 55.00% (28.28 At.%)		Cu: 40.00% (67.39 At.%) Au: 60.00% (32.61 At.%)		Cu: 35.00% (62.54 At.%) Au: 65.00% (37.46 At.%)		Cu: 30.00% (57.05 At.%) Au: 70.00% (42.95 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	8.48*‡	1	9.34*‡	1	10.14*‡	1	10.88*‡	1	11.43*‡	1	11.82*‡
4	8.48‡	4	9.34‡	4	10.14‡	4	10.88‡	4	11.43‡	4	11.82‡
7	8.48*‡	7	9.34*‡	7	10.14*‡	7	10.88*‡	7	11.43*‡	7	11.82*‡
10	8.48*‡	10	9.34*‡	10	10.14*‡	10	10.88*‡	10	11.43*‡	10	11.82*‡
15	8.48*‡	15	9.35*‡	15	10.15*‡	15	10.88*‡	15	11.43*‡	15	11.83*‡
20	8.49‡	20	9.37‡	20	10.17‡	20	10.89‡	20	11.44‡	20	11.84‡
25	8.51‡	25	9.39‡	25	10.19*‡	25	10.90*‡	25	11.46*‡	25	11.86*‡
30	8.54‡	30	9.42‡	30	10.22*‡	30	10.93*‡	30	11.50*‡	30	11.90*‡
40	8.61‡	40	9.48‡	40	10.28*‡	40	11.00*‡	40	11.57*‡	40	11.97*‡
50	8.67‡	50	9.55‡	50	10.36*‡	50	11.08*‡	50	11.65*‡	50	12.04*‡
60	8.74‡	60	9.62‡	60	10.42*‡	60	11.15*‡	60	11.73*‡	60	12.12*‡
70	8.80‡	70	9.68‡	70	10.49‡	70	11.22‡	70	11.80‡	70	12.20‡
80	8.87‡	80	9.74‡	80	10.56*‡	80	11.30*‡	80	11.87*‡	80	12.27*‡
90	8.94‡	90	9.81‡	90	10.63*‡	90	11.37*‡	90	11.95*‡	90	12.35*‡
100	9.00‡	100	9.88‡	100	10.70*‡	100	11.44*‡	100	12.02*‡	100	12.43*‡
150	9.33	150	10.22	150	11.05*	150	11.80*	150	12.40*	150	12.81*
200	9.66	200	10.57	200	11.41*	200	12.18*	200	12.78*	200	13.20*
250	10.00	250	10.91	250	11.76*	250	12.54*	250	13.16*	250	13.59*
273	10.16	273	11.07	273	11.92	273	12.70	273	13.33	273	13.77
293	10.30	293	11.20	293	12.06	293	12.85	293	13.48	293	13.93
300	10.35	300	11.25	300	12.11*	300	12.90*	300	13.54*	300	13.99*
350	10.68	350	11.60	350	12.46*	350	13.27*	350	13.92*	350	14.38*
400	11.03	400	11.94	400	12.81	400	13.65	400	14.31*	400	14.78*
500	11.72‡	500	12.65‡	500	13.54‡	500	14.40‡	500	15.09*‡	500	15.58*‡
600	12.43‡	600	13.38‡	600	14.30‡	600	15.17‡	600	15.89*‡	600	16.40*‡
700	13.16‡	700	14.13‡	700	15.07‡	700	15.96‡	700	16.69*‡	700	17.24*‡
800	13.92‡	800	14.91‡	800	15.87‡	800	16.76‡	800	17.53*‡	800	18.11*‡
900	14.71‡	900	15.71‡	900	16.71‡	900	17.61‡	900	18.42*‡	900	19.02*‡
1000	15.53*‡	1000	16.53*‡	1000	17.60*‡	1000	18.52*‡	1000	19.36*‡	1000	20.00*‡
1100	16.36*‡	1100	17.37*‡	1100	18.53*‡	1100	19.47*‡	1100	20.33*‡	1100	20.96*‡
1200	17.19*‡	1200	18.23*‡	1200	19.47*‡	1200	20.46*‡	1196	21.30*‡	1188	21.85*‡
1236	17.49*‡	1226	18.45*‡	1216	19.62*‡	1206	20.51*‡				

† Uncertainties in the electrical resistivity values are as follows:

55.00 Cu - 45.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
50.00 Cu - 50.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
45.00 Cu - 55.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
40.00 Cu - 60.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
35.00 Cu - 65.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
30.00 Cu - 70.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 15. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-GOLD ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Cu: 25.00% (50.82 At.%) Au: 75.00% (49.18 At.%)		Cu: 20.00% (43.66 At.%) Au: 80.00% (56.34 At.%)		Cu: 15.00% (35.36 At.%) Au: 85.00% (64.64 At.%)		Cu: 10.00% (25.62 At.%) Au: 90.00% (74.38 At.%)		Cu: 5.00% (14.03 At.%) Au: 95.00% (85.97 At.%)		Cu: 3.00% (8.75 At.%) Au: 97.00% (91.25 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	11.95‡	1	11.72*‡	1	10.75*‡	1	8.72*‡	1	5.27*‡	1	3.44*‡
4	11.95‡	4	11.72‡	4	10.75‡	4	8.72‡	4	5.27‡	4	3.44‡
7	11.95‡	7	11.72*‡	7	10.75*‡	7	8.72*‡	7	5.27*‡	7	3.44*‡
10	11.96‡	10	11.72*‡	10	10.75*‡	10	8.72*‡	10	5.28*‡	10	3.44*‡
15	11.97‡	15	11.73*‡	15	10.76*‡	15	8.72*‡	15	5.29*‡	15	3.45*‡
20	11.98‡	20	11.75‡	20	10.77‡	20	8.73‡	20	5.31‡	20	3.46‡
25	12.00‡	25	11.77*‡	25	10.79*‡	25	8.75‡	25	5.33*‡	25	3.49*‡
30	12.04‡	30	11.80*‡	30	10.83*‡	30	8.78‡	30	5.36*‡	30	3.52*‡
40	12.12‡	40	11.87*‡	40	10.91*‡	40	8.86‡	40	5.44*‡	40	3.60*‡
50	12.20‡	50	11.95*‡	50	10.99*‡	50	8.94‡	50	5.52*‡	50	3.68*‡
60	12.27‡	60	12.03*‡	60	11.07*‡	60	9.02‡	60	5.60*‡	60	3.76*‡
70	12.35‡	70	12.10‡	70	11.15‡	70	9.10‡	70	5.68‡	70	3.84‡
80	12.43‡	80	12.18*‡	80	11.22*‡	80	9.17‡	80	5.75*‡	80	3.92*‡
90	12.51‡	90	12.26*‡	90	11.30*‡	90	9.25‡	90	5.83*‡	90	4.00*‡
100	12.59‡	100	12.35*‡	100	11.38*‡	100	9.33‡	100	5.91*‡	100	4.08*‡
150	12.98	150	12.74*	150	11.78*	150	9.73	150	6.30*	150	4.48*
200	13.36	200	13.12*	200	12.18*	200	10.12	200	6.68*	200	4.86*
250	13.75	250	13.52*	250	12.57*	250	10.52	250	7.07*	250	5.29*
273	13.93	273	13.70*	273	12.75	273	10.70	273	7.25	273	5.47
293	14.09	293	13.86*	293	12.91	293	10.86	293	7.41*	293	5.64
300	14.14	300	13.92*	300	12.96*	300	10.91	300	7.46*	300	5.69*
350	14.54	350	14.32*	350	13.36*	350	11.31	350	7.87	350	6.10
400	14.94	400	14.73*	400	13.77	400	11.72	400	8.28	400	6.49
500	15.78‡	500	15.57*‡	500	14.60‡	500	12.58*‡	500	9.14‡	500	7.32‡
600	16.63‡	600	16.41*‡	600	15.44‡	600	13.47*‡	600	10.02‡	600	8.19‡
700	17.49‡	700	17.26*‡	700	16.29‡	700	14.38*‡	700	10.92‡	700	9.10‡
800	18.38‡	800	18.14*‡	800	17.16‡	800	15.32*‡	800	11.86‡	800	10.05‡
900	19.31‡	900	19.09*‡	900	18.15‡	900	16.30*‡	900	12.84‡	900	11.05‡
1000	20.32‡	1000	20.12*‡	1000	19.23‡	1000	17.36*‡	1000	13.90*‡	1000	12.13*‡
1100	21.34‡	1100	21.14*‡	1100	20.30‡	1100	16.47*‡	1100	15.01*‡	1100	13.30*‡
1184	22.29‡	1182	22.09*‡	1185	21.30‡	1199	19.61*‡	1200	16.14*‡	1200	14.56*‡
								1241	16.60*‡	1270	15.44*‡

† Uncertainties in the electrical resistivity values are as follows:

25.00 Cu - 75.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
20.00 Cu - 80.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
15.00 Cu - 85.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
10.00 Cu - 90.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
5.00 Cu - 95.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
3.00 Cu - 97.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 15. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-GOLD ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

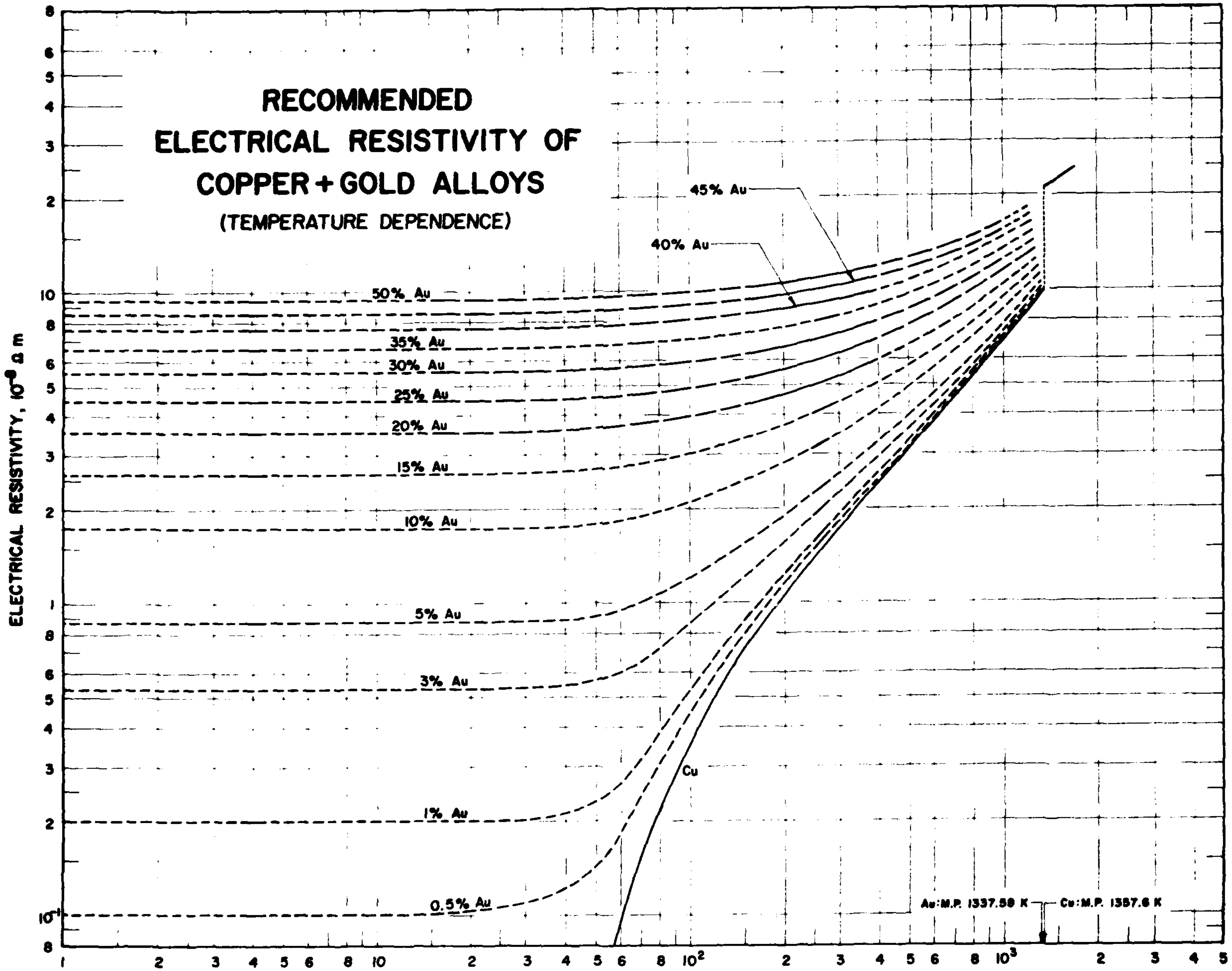
Cu: 1.00% (3.04 At.%) Au: 99.00% (96.96 At.%)		Cu: 0.50% (1.53 At.%) Au: 99.50% (98.47 At.%)		Cu: 0.00% (0.00 At.%) Au: 100.00% (100.00 At.%)				
T	ρ	T	ρ	T	ρ			
1	1.40‡	1	0.770*‡	1	0.0220			
4	1.40‡	4	0.770‡	4	0.0220			
7	1.40‡	7	0.770*‡	7	0.0221			
10	1.40‡	10	0.770*‡	10	0.0226			
15	1.40‡	15	0.770*‡	15	0.0258			
20	1.41‡	20	0.780‡	20	0.0346‡			
25	1.43‡	25	0.801*‡	25	0.0503‡			
30	1.45‡	30	0.828*‡	30	0.0727‡			
40	1.51‡	40	0.892*	40	0.141‡			
50	1.60‡	50	0.966*‡	50	0.222			
60	1.68‡	60	1.04*‡	60	0.309			
70	1.76‡	70	1.13‡	70	0.396			
80	1.84‡	80	1.21*‡	80	0.482			
90	1.92‡	90	1.29*‡	90	0.567			
100	2.00‡	100	1.37*‡	100	0.652			
150	2.41	150	1.78*	150	1.063			
200	2.81	200	2.18*	200	1.464			
250	3.22	250	2.59*	250	1.865			
273	3.40	273	2.78	273	2.052			
293	3.57	293	2.94*	293	2.214			
300	3.62	300	3.00*	300	2.271			
350	4.03	350	3.41*	350	2.683			
400	4.45	400	3.82*	400	3.102			
500	5.30*‡	500	4.68*‡	500	3.962			
600	6.18*‡	600	5.62*‡	600	4.853			
700	7.10*‡	700	6.51*‡	700	5.780			
800	8.07*‡	800	7.45*‡	800	6.755			
900	9.10*‡	900	8.47*‡	900	7.787			
1000	10.23*‡	1000	9.57*‡	1000	8.884			
1100	11.46*‡	1100	10.77*‡	1100	10.057			
1200	12.77*‡	1200	12.10*‡	1200	11.312			
1296	14.07*‡	1300	13.47*‡	1300	12.632			
		1323	13.73*‡	1337.58	13.146(s)			
				1338	31.06(ℓ)			
				1700	36.26			

† Uncertainties in the electrical resistivity values are as follows:

1.00 Cu - 99.00 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
0.50 Cu - 99.50 Au: ±7% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
0.00 Cu - 100.00 Au: ±1% up to 10 K, ±2.5% above 10 K to 15 K, ±6% above 15 K to 40 K, ±3% above 40 k to 80 K, ±1% above 80 K to 500 K, and ±2.5% above 500 K.

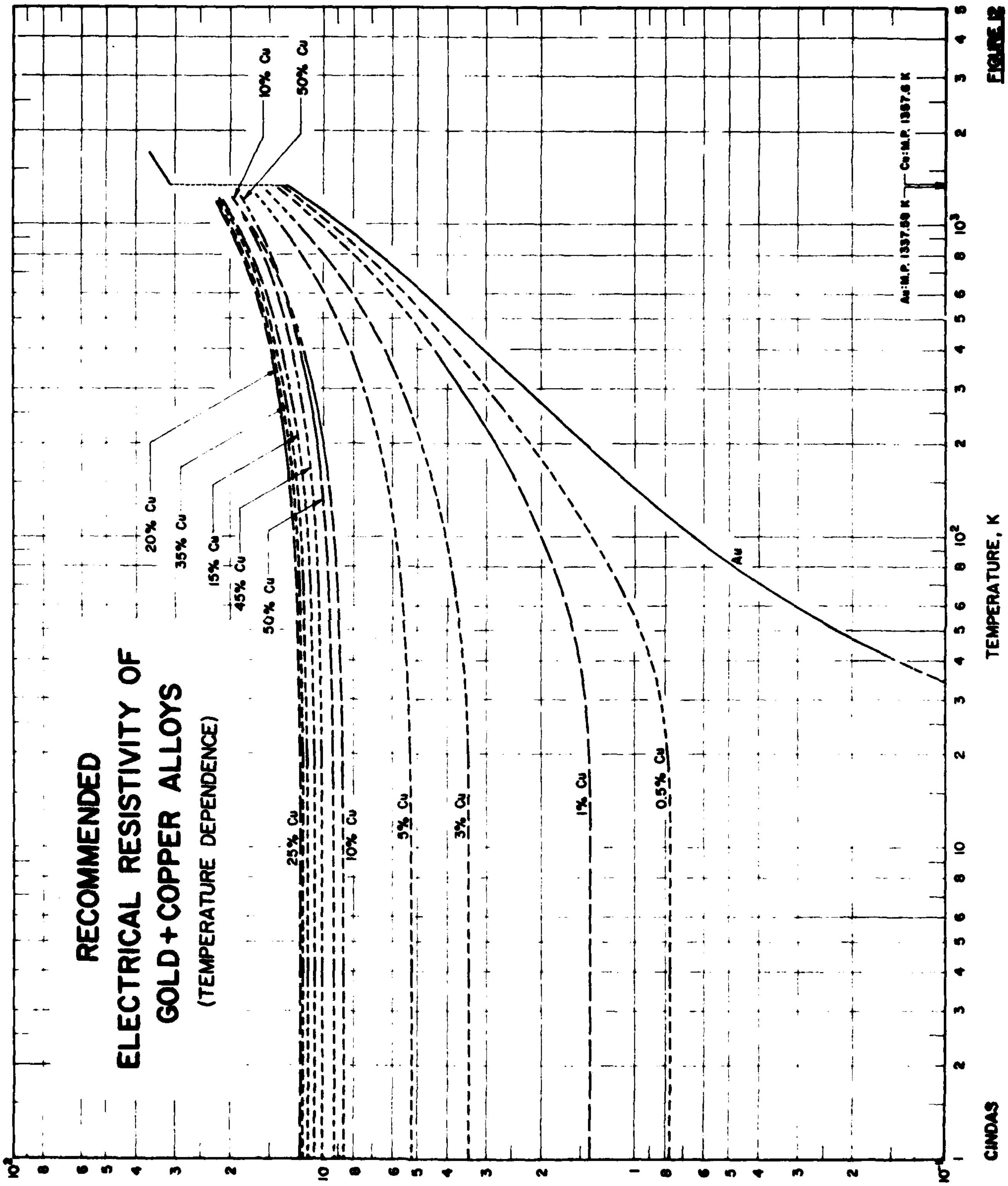
‡ Provisional value.

* In temperature range where no experimental data are available.



CINDAS

FIGURE 11



RECOMMENDED
ELECTRICAL RESISTIVITY OF
GOLD + COPPER ALLOYS
(TEMPERATURE DEPENDENCE)
10% Cu
50% Cu
20% Cu
35% Cu
15% Cu
45% Cu
50% Cu
25% Cu
10% Cu
5% Cu
3% Cu
1% Cu
0.5% Cu
Au
Au: M.P. 1337.58 K
Cu: M.P. 1357.6 K
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE, K
CINDAS

FIGURE 12

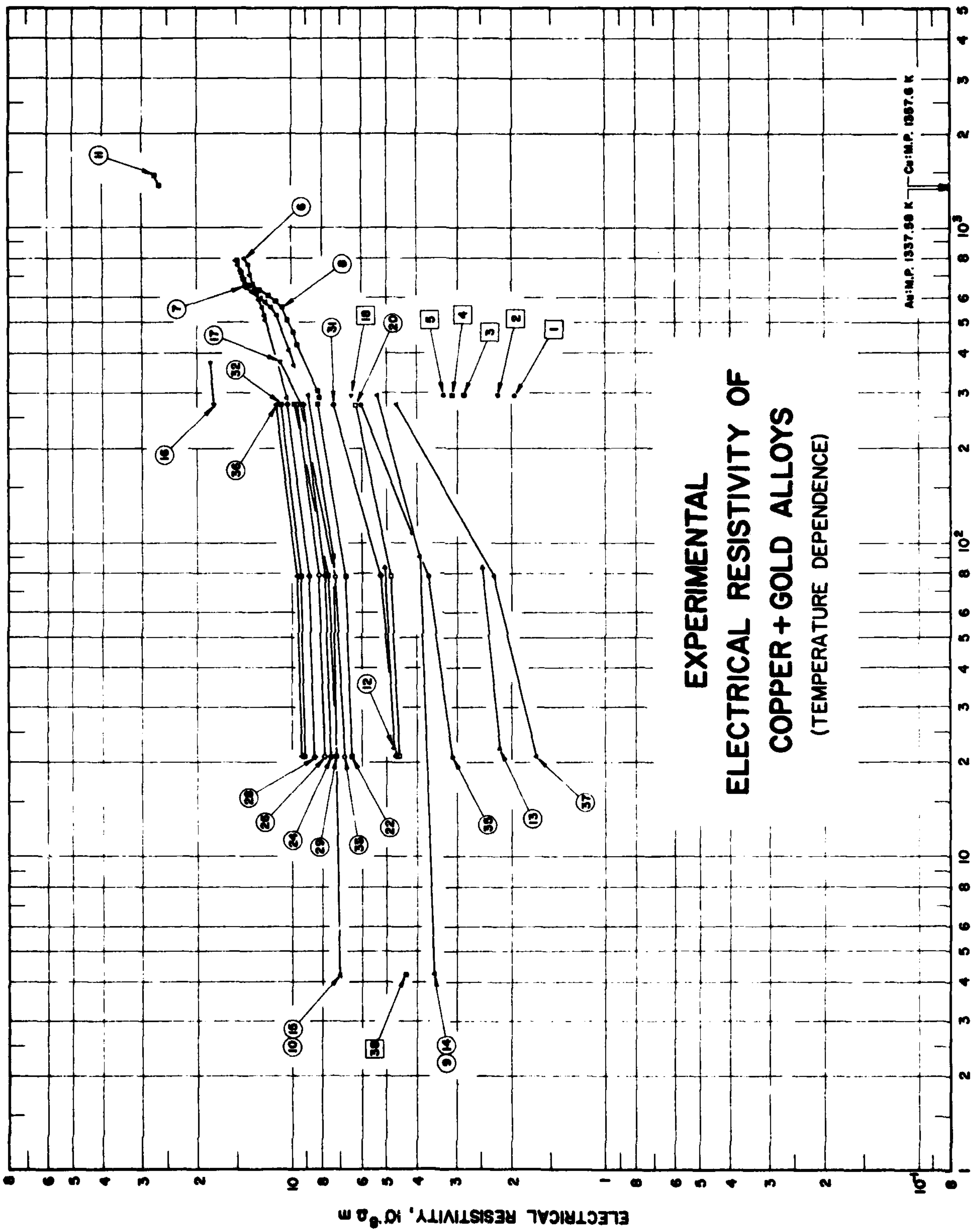

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
COPPER + GOLD ALLOYS
(TEMPERATURE DEPENDENCE)
TEMPERATURE, K
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
Au: M.P. 1337.58 K
Cu: M.P. 1357.6 K
CINDAS

FIGURE 13

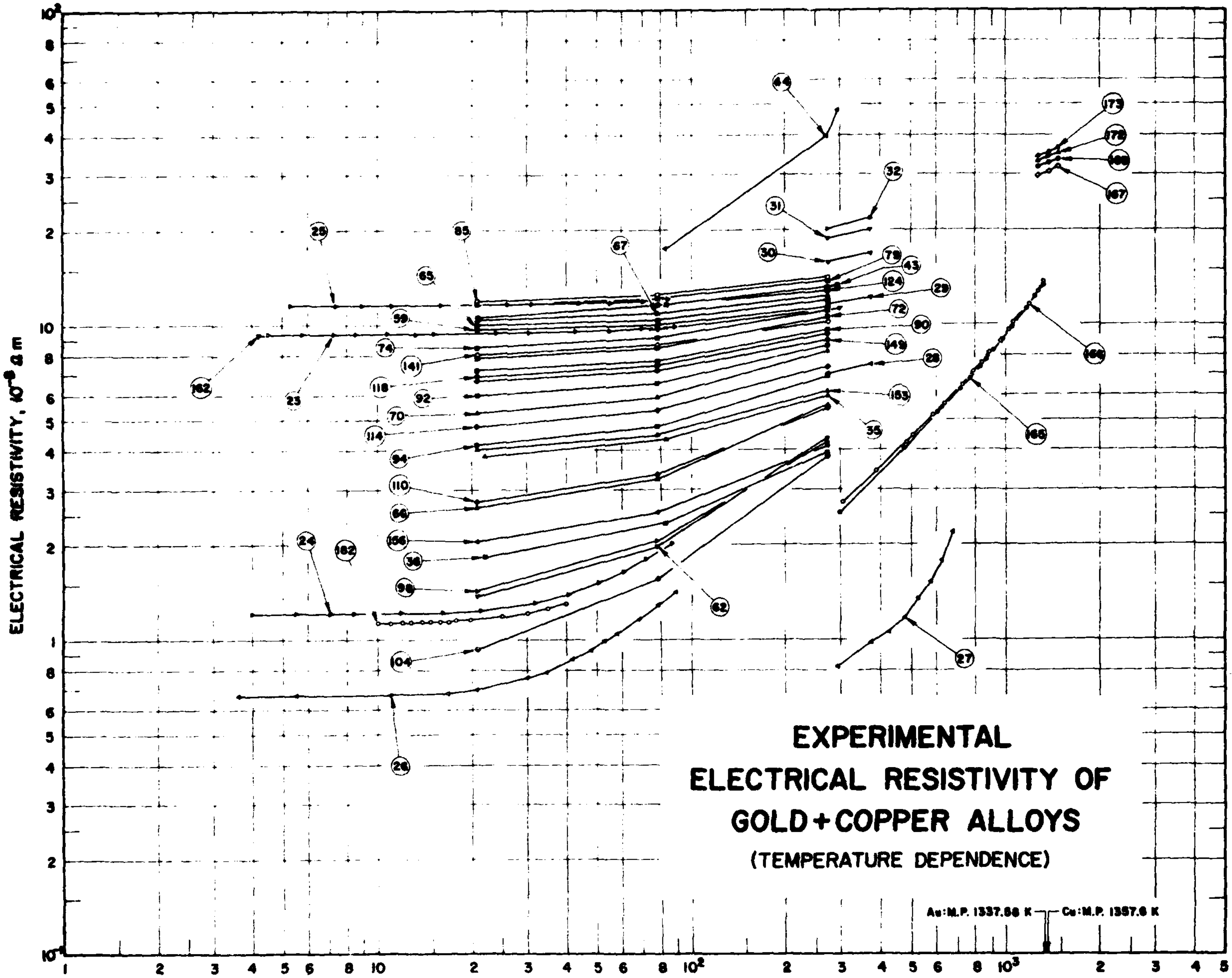


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FIGURE 14

TABLE 16. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + GOLD ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Au	Composition (continued), Specifications, and Remarks
1	126	Linde, J.O.	1932		291.2			1.53	Calculated composition (0.500 a/o Au).
2	126	Linde, J.O.	1932		291.2			3.00	Calculated composition (0.988 a/o Au).
3	126	Linde, J.O.	1932		291.2			5.92	Calculated composition (1.99 a/o Au).
4	126	Linde, J.O.	1932		291.2			7.05	Calculated composition (2.39 a/o Au).
5	126	Linde, J.O.	1932		291.2			8.75	Calculated composition (3.00 a/o Au).
6	123	Borelius, G., Johansson, C.H., and Linde, J.O.	1928	V	286-795			43.97	Calculated composition (20.2 a/o Au); 1 x 1 x 20 mm; initial materials, melted in quartz tube, heat-treated near melting temperature and cooled in a way to keep rolling condition, rolled to 1 x 1 mm square wire, heat-treated again near melting temperature; measurements made during both heating and cooling.
7	123	Borelius, G., et al.	1928	V	363-787			47.51	Calculated composition (22.6 a/o Au); similar to the above specimen; measurements made during heating.
8	123	Borelius, G., et al.	1928	V	286-787			47.51	The above specimen measured during cooling.
9	125	Tainsh, R.J. and White, G.K.	1962	A	4.2-293			20.1	Calculated composition (7.5 a/o Au); rod specimen 3 to 5 mm in diameter and 6 cm long; annealed at 750 C.
10	125	Tainsh, R.J. and White, G.K.	1962	A	4.2-293			38.0	Calculated composition (16.5 a/o Au); similar to the above specimen.
11	127	Roll, A. and Motz, H.	1957	R	1373, 1473			30.7	Calculated composition (12.5 a/o Au); prepared from electrolytic copper and 99.95 pure gold; $d\rho/dT = 0.0106\ \mu\Omega\ cm\ K^{-1}$.
12	128	Gruneisen, E. and Reddemann, H.	1934		22, 83		75.2	24.8	Calculated composition; polycrystalline; form factor 1.53×10^3.
13	128	Gruneisen, E. and Reddemann, H.	1934		22, 83		87.4	12.6	Calculated composition; polycrystalline; form factor 2.61×10^3.
14	129	Kemp, W.R.G., Klemens, P.G., and Tainsh, R.J.	1957	A	4.2-293			20.1	Calculated composition (7.5 a/o Au); specimen 8 cm long and 0.5 cm in diameter; annealed at 750 C for 1 hr.
15	129	Kemp, W.R.G., et al.	1957	A	4.2-293			38.0	Calculated composition (16.5 a/o Au); similar to the above specimen.
16	130	Sedstrom, E.	1919		273, 373		55.3	44.7	Calculated composition (79.3 a/o Cu); rolled and drawn to wire 1 mm diameter; heated to near melting point for 1/2 hr.
17	130	Sedstrom, E.	1919		273, 373		73.5	26.0	Calculated composition (89.6 a/o Cu); similar to the above specimen.
18	131	Röhl, H.	1933		291.2	I		25.05	5 mm diameter x 10 cm long; heat-treated at 1073 K for 4 hr, then quenched.
19*	131	Röhl, H.	1933		291.2	I			Similar to the above specimen but heat-treated at 573 to 673 K for 20 hr and slowly cooled.
20	132	Pospisil, V.	1933	V	21-273	1		25.6	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 10.60 g cm^{-3}.
21*	132	Pospisil, V.	1933	V	21-273	1			The above specimen annealed at 300 to 400 C for one week.
22	132	Pospisil, V.	1933	V	21-273	2		35.4	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 10.84 g cm^{-3}.

* Not shown in figure.

TABLE 16. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + GOLD ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Au	Composition (continued), Specifications, and Remarks
23*	132	Pospisil, V.	1933	V	21-273	2		35.4	The above specimen annealed at 300 to 400 C for one week.
24	132	Pospisil, V.	1933	V	21-273	3		39.7	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 11.18 g cm^{-3}.
25*	132	Pospisil, V.	1933	V	21-273	3		39.7	The above specimen annealed at 300 to 400 C for one week.
26	132	Pospisil, V.	1933	V	21-273	4		42.0	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 11.41 g cm^{-3}.
27*	132	Pospisil, V.	1933	V	21-273	4		42.0	The above specimen annealed at 300 ro 400 C for one week.
28	132	Pospisil, V.	1933	V	21-273	5		43.7	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 11.50 g cm^{-3}.
29	132	Pospisil, V.	1933	V	21-273	5		43.7	The above specimen annealed at 300 to 400 C for one week.
30*	132	Pospisil, V.	1933	V	21-273	5a		45.3	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 11.69 g cm^{-3}.
31	132	Pospisil, V.	1933	V	21-273	5a		45.3	The above specimen annealed at 300 to 400 C for one week.
32	132	Pospisil, V.	1933	V	21-273	6		46.0	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 11.71 g cm^{-1}.
33	132	Pospisil, V.	1933	V	21-273	6		46.0	The above specimen annealed at 300 to 400 C for one week.
34*	132	Pospisil, V.	1933	V	21-273	7		48.0	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 11.81 g cm^{-3}.
35	132	Pospisil, V.	1933	V	21-273	7		48.0	The above specimen annealed at 300 to 400 C for one week.
36	132	Pospisil, V.	1933	V	21-273	7		49.6	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 12.05 g cm^{-3}.
37	132	Pospisil, V.	1933	V	21-273	7		49.6	The above specimen annealed at 300 to 400 C for one week.
38	90	Leaver, A.D.W. and Charsley, P.	1971	A	4.2	10 Au		25.4	Polycrystalline; obtained from International Research and Development Co.; annealed.
39*	90	Leaver, A.D.W. and Charsley, P.	1971	A	4.2	10 Au		25.4	The above specimen tensile strained 13.4% under a stress of 36.68 kg mm^{-2}.

* Not shown in figure.

TABLE 17. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + GOLD ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

T	ρ
DATA SET 1	
291.2	1.954
DATA SET 2	
291.2	2.200
DATA SET 3	
291.2	2.811
DATA SET 4	
291.2	3.072
DATA SET 5	
291.2	3.278
DATA SET 6	
286.2	10.44
505.2	12.10
524.2	12.22
553.2	12.45
585.2	12.79
611.2	12.95
634.2	13.04*
643.2	13.10*
650.2	13.10
654.2	13.23*
660.2	13.25*
663.2	13.20*
672.2	13.31*
674.2	13.33*
683.2	13.38
702.2	13.51*
713.2	13.55
723.2	13.64*
732.2	13.70*
738.2	13.75*
747.2	13.73*
754.2	13.75*
757.2	13.80
765.2	13.92*
775.2	13.93*
785.2	14.00*
795.2	14.06
DATA SET 7	
363.2	9.82
406.2	10.18
522.2	11.16
556.2	11.79
574.2	12.11
581.2	12.21*
586.2	12.34*
595.2	12.55
604.2	12.77
609.2	12.92*
614.2	13.13
626.2	13.47*
631.2	13.73*
636.2	13.93*
643.2	14.11*
652.2	14.11*
660.2	14.11*
670.2	14.16*
684.2	14.29
693.2	14.35*
713.2	14.49
729.2	14.56*
737.2	14.64
749.2	14.74*
757.2	14.83
787.2	15.04
DATA SET 8	
286.2	8.19
302.2	8.26
424.2	9.55
400.2	9.84
472.2	10.01*
485.2	10.13
503.2	10.33
532.2	10.55*
551.2	10.75
565.2	10.94*
577.2	11.13*
588.2	11.34
597.2	11.57*
607.2	11.92
630.2	12.73
639.2	13.06*
642.2	13.26*
646.2	13.48*
DATA SET 8 (cont.)	
650.2	13.64
654.2	13.85*
658.2	14.05*
660.2	14.11*
680.2	14.15
720.2	14.47
727.2	14.56*
737.2	14.64*
749.2	14.74*
757.2	14.83
784.2	14.95*
787.2	15.04
DATA SET 9	
4.2	3.53
90	3.91
293	5.37
DATA SET 10	
4.2	7.04
90	7.38
293	8.89
DATA SET 11	
1373	26.3
1473	27.4
DATA SET 12	
22.2	4.71
83.2	5.09
DATA SET 13	
22.2	2.172
83.2	2.487
DATA SET 14	
4.2	3.53
90	3.91
293	5.37
DATA SET 15	
4.2	7.04
90	7.38
293	8.89
DATA SET 16	
273.2	17.54
373.2	18.18
DATA SET 17	
273.2	9.35
373.2	10.99
DATA SET 18	
291.2	6.49
DATA SET 19*	
291.2	6.59
DATA SET 20	
20.8	4.54
78.2	4.85
273.2	6.27
DATA SET 21*	
20.8	4.51
78.2	4.81
273.2	6.22
DATA SET 22	
20.8	6.43
78.2	6.76
273.2	8.21
DATA SET 23*	
20.8	6.48
78.2	6.82
273.2	8.27
DATA SET 24	
20.8	7.46
78.2	7.81
273.2	9.28
DATA SET 25*	
20.8	7.54
78.2	7.89
273.2	9.39
DATA SET 26	
20.8	7.85
78.2	8.20
273.2	9.65
DATA SET 27*	
20.8	7.75
78.2	8.16
273.2	9.78
DATA SET 28	
20.8	8.44
78.2	8.80
273.2	10.33
DATA SET 29	
20.8	7.22
78.2	7.78
273.2	9.77
DATA SET 30*	
20.8	8.49
78.2	8.85
273.2	10.32
DATA SET 31	
20.8	4.66
78.2	5.21
273.2	7.35
DATA SET 32	
20.8	9.03
78.2	9.37
273.2	10.81
DATA SET 33	
20.8	6.80
78.2	7.30
273.2	9.23
DATA SET 34*	
20.8	8.99
78.2	9.37
273.2	10.86
DATA SET 35	
20.8	3.09
78.2	3.66
273.2	6.00
DATA SET 36	
20.8	9.29
78.2	9.66
273.2	11.16
DATA SET 37	
20.8	1.66
78.2	2.27
273.2	4.64
DATA SET 38	
4.2	4.386
DATA SET 39*	
4.2	4.444

* Not shown in figure.

TABLE 18. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
1*	123	Borelius, G., Johansson, C.H., and Linde, J.D.	1928	V	289-723			49.18	Calculated composition (75 a/o Cu); 1 x 1 x 20 mm; initial materials melted in quartz tube, heat-treated near melting temperature, cooled in a way to keep rolling condition, rolled to 1 x 1 mm square wire; heat-treated again near melting temperature; measured during heating.
2*	123	Borelius, G., et al.	1928	V	283-723			49.18	The above specimen measured during cooling.
3*	123	Borelius, G., et al.	1928	V	277-656			49.18	The above specimen quenched; measured during heating.
4*	123	Borelius, G., et al.	1928	V	391-732			45.71	Calculated composition (72.3 a/o Cu); same dimensions, fabrication method, and heat-treatment as the above specimen for curve no. 1; measured during heating.
5*	123	Borelius, G., et al.	1928	V	282-732			45.71	The above specimen measured during cooling.
6*	123	Borelius, G., et al.	1928	V	287-700			42.83	Calculated composition (69.9 a/o Cu); similar to the above specimen; measured during heating.
7*	123	Borelius, G., et al.	1928	V	283-700			42.83	The above specimen measured during cooling.
8*	123	Borelius, G., et al.	1928	V	283-707			28.28	Calculated composition (55 a/o Cu); similar to the above specimen; measured during heating.
9*	123	Borelius, G., et al.	1928	V	286-707			28.28	The above specimen measured during cooling.
10*	123	Borelius, G., et al.	1928	V	18-327			24.39	Calculated composition (50 a/o Cu); same dimensions, fabrication method, and heat-treatment as the above specimen; quenched; measured during heating.
11*	123	Borelius, G., et al.	1928	V	15-327			24.39	The above specimen measured during cooling.
12*	123	Borelius, G., et al.	1928	V	15-419			24.39	The above specimen remeasured during heating.
13*	123	Borelius, G., et al.	1928	V	17-419			24.39	The above specimen again measured during cooling.
14*	123	Borelius, G., et al.	1928	V	17-427			24.39	The above specimen reheated for measurement.
15*	123	Borelius, G., et al.	1928	V	404-427			24.39	The above specimen remeasured.
16*	123	Borelius, G., et al.	1928	V	448-467			24.39	The above specimen remeasured during heating.
17*	123	Borelius, G., et al.	1928	V	10-448			24.39	The above specimen measured during cooling.
18*	123	Borelius, G., et al.	1928	V	10-379			24.39	The above specimen reheated.
19*	123	Borelius, G., et al.	1928	V	100-379			24.39	The above specimen measured during cooling.
20*	123	Borelius, G., et al.	1928	V	293			24.39	The above specimen repeatedly annealed.
21*	123	Borelius, G., et al.	1928	V	290-723			20.96	Calculated composition (45 at.% Cu); similar to the specimen for Data Set No. 1; measured during heating.
22*	123	Borelius, G., et al.	1928	V	290-723			20.96	The above specimen measured during cooling.

* Not shown in figure.

TABLE 18. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Composition (weight percent) Cu	Composition (continued), Specifications, and Remarks
23	124	Passaglia, E. and Love, W.F.	1955	A	4.5-89			49.18	Calculated composition (75 a/o Cu); prepared from 99.999 pure copper obtained from Johnson-Mathey and 99.99 pure gold obtained from J. Bishop and Co. by melting in sealed Vycor tubes under high vacuum, shaken vigorously to provide a homogeneous melt; quenched; electrical resistivity values converted from the reported γ, the ratio of resistance and ice point resistance, by the equation, $\rho(T) = \gamma\rho_i$, using the ice point resistivity ρ_i value extrapolated from resistivity value at 20 C of Johansson and Linde, ($\rho_i = 11.201\ \mu\Omega$ cm).
24	124	Passaglia, E. and Love, W.F.	1955	A	4.0-86			49.18	The above specimen annealed at 850 C for 48 hr ($\rho_i = 4.49\ \mu\Omega$ cm).
25	124	Passaglia, E. and Love, W.F.	1955	A	5.3-84			24.39	Calculated composition (50 a/o Cu); similar to the above specimen for Data Set No. 23 ($\rho_i = 13.915\ \mu\Omega$ cm).
26	124	Passaglia, E. and Love, W.F.	1955	A	3.6-89			24.39	The above specimen annealed at 850 C for 48 hr ($\rho_i = 3.63\ \mu\Omega$ cm).
27	133	Jones, F.W. and Sykes, C.	1938		293-673			49.2	Calculated composition (75 a/o Cu); *0.4 cm diameter x 12.5 cm long*; obtained from Johnson-Matthey; cold-rolled to 0.1 cm thick, annealed at 1223 K for 4 hr, cold-drawn to 0.04 cm in diameter, and reannealed at 823 K for 30 min in vacuum; smoothed values reported.
28	130	Sedström, E.	1919		273, 373		96.73	3.27	Calculated composition (9.5 a/o Cu); rolled and drawn to 1 mm diameter wire; annealed close to melting point for 1/2 hr.
29	130	Sedström, E.	1919		273, 373		92.55	7.45	Calculated composition (20.0 a/o Cu); similar to the above specimen.
30	130	Sedström, E.	1919		273, 373		87.77	12.23	Calculated composition (30.2 a/o Cu); similar to the above specimen.
31	130	Sedström, E.	1919		273, 373			19.2	Calculated composition (42.4 a/o Cu); similar to the above specimen.
32	130	Sedström, E.	1919		273, 373		59.25	40.75	Calculated composition (58.1 a/o Cu); similar to the above specimen.
33*	128	Gruneisen, E. and Reddemann, H.	1934		83		89.6	10.4	Calculated composition; polycrystalline; cast.
34*	128	Gruneisen, E. and Reddemann, H.	1934		273		89.6	10.4	The above specimen annealed at 365 C for 40 hr.
35	128	Gruneisen, E. and Reddemann, H.	1934		22-273		96.9	3.10	Calculated composition; polycrystalline; cast.
36	128	Gruneisen, E. and Reddemann, H.	1934		22-273		98.43	1.57	Similar to the above specimen.
37*	128	Gruneisen, E. and Reddemann, H.	1934		83		50.1	49.9	Calculated composition; polycrystalline; cast; quenched from 800 C.
38*	128	Gruneisen, E. and Reddemann, H.	1934		83, 273		50.1	49.9	The above specimen annealed at ~400 C for 20 hr.
39*	128	Gruneisen, E. and Reddemann, H.	1934		83, 273		50.1	49.9	The above specimen annealed at ~360 C for 32 hr.
40*	128	Gruneisen, E. and Reddemann, H.	1934		273		50.1	49.9	The above specimen annealed at ~320 C for 2 hr and then quenched.

* Not shown in figure.

TABLE 18. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
41*	128	Gruneisen, E. and Reddemann, H.	1934		83, 273		50.1	49.9	The above specimen measured after 5 months.
42*	128	Gruneisen, E. and Reddemann, H.	1934		22, 83		50.1	49.9	The above specimen annealed at ~325 C for 30 hr.
43	128	Gruneisen, E. and Reddemann, H.	1934		83-292		75.6	24.4	Calculated composition; polycrystalline; cast; quenched from 800 C.
44	128	Gruneisen, E. and Reddemann, H.	1934		83-293		75.6	24.4	The above specimen annealed at 360 C for 22 hr.
45*	128	Gruneisen, E. and Reddemann, H.	1934		83, 273		75.6	24.4	The above specimen annealed at 345 C for 30 hr.
46*	128	Gruneisen, E. and Reddemann, H.	1934		83, 273		75.6	24.4	The above specimen annealed at 325 C for 30 hr.
47*	128	Gruneisen, E. and Reddemann, H.	1934		83		75.6	24.4	The above specimen annealed at 800 C for 2 hr, then quenched.
48*	128	Gruneisen, E. and Reddemann, H.	1934		83		75.6	24.4	The above specimen measured after 4 months.
49*	128	Gruneisen, E. and Reddemann, H.	1934		83, 273		75.6	24.4	The above specimen annealed at ~325 C for 30 hr.
50*	131	Röhl, H.	1933		291.2	II	50.75	49.25	5 mm diameter x 10 cm long; heat-treated at 800 C for 4 hr and quenched.
51*	131	Röhl, H.	1933		291.2	II	50.75	49.25	The above specimen annealed at 300 to 400 C for 20 hr and cooled slowly.
52*	131	Röhl, H.	1933		291.2	II	50.75	49.25	The above specimen reheated to 800 C for 4 hr and quenched.
53*	131	Röhl, H.	1933		291.2	II	50.75	49.25	The above specimen reannealed at 300 to 400 C for 20 hr and cooled slowly.
54*	131	Röhl, H.	1933		291.2	IIIa	75.70	24.30	5 mm diameter x 10 cm long; heat-treated at 800 C for 4 hr and quenched.
55*	131	Röhl, H.	1933		291.2	IIIa	75.70	24.30	The above specimen annealed at 300 to 400 C for 20 hr and cooled slowly.
56*	131	Röhl, H.	1933		291.2	IV	89.63	10.37	5 mm diameter x 10 cm long; annealed at 300 to 400 C for 20 hr and cooled slowly.
57*	131	Röhl, H.	1933		291.2	IV	89.63	10.37	The above specimen reheated to 800 C for 4 hr and quenched.
58*	131	Röhl, H.	1933		291.2	IV	89.63	10.37	The above specimen reannealed at 300 to 400 C for 20 hr and cooled slowly.
59	132	Pospisil, V.	1933	V	21-273	9	50.8	49.2	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 12.00 g cm^{-3}.
60*	132	Pospisil, V.	1933	V	21-273	9	50.8	49.2	The above specimen annealed at 300 to 400 C for one week.
61*	132	Pospisil, V.	1933	V	21-273	9a	50.8	49.2	Similar to the specimen for Data Set No. 59 but density 12.10 g cm^{-3}.
62	132	Pospisil, V.	1933	V	21-273	9a	50.8	49.2	The above specimen annealed at 300 to 400 C for one week.
63*	132	Pospisil, V.	1933	V	21-273	10	52.2	47.8	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 11.97 g cm^{-3}.
64*	132	Pospisil, V.	1933	V	21-273	10	52.2	47.8	The above specimen annealed at 300 to 400 C for one week.

* Not shown in figure.

TABLE 18. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
65	132	Pospisil, V.	1933	V	21-273	11	54.2	45.8	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 12.34 g cm^{-3}.
66	132	Pospisil, V.	1933	V	21-273	11	54.2	45.8	The above specimen annealed at 300 to 400 C for one week.
67	132	Pospisil, V.	1933	V	21-273	12	55.9	44.1	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 12.45 g cm^{-3}.
68*	132	Pospisil, V.	1933	V	21-273	12	55.9	44.1	The above specimen annealed at 300 to 400 C for one week.
69*	132	Pospisil, V.	1933	V	21-273	13	57.0	43	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 12.43 g cm^{-3}.
70	132	Pospisil, V.	1933	V	21-273	13	57.0	43	The above specimen annealed at 300 to 400 C for one week.
71*	132	Pospisil, V.	1933	V	21-273	14	59.3	40.7	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 12.78 g cm^{-3}.
72	132	Pospisil, V.	1933	V	21-273	14	59.3	40.7	The above specimen annealed at 300 to 400 C for one week.
73*	132	Pospisil, V.	1933	V	21-273	15	60.5	39.5	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 13.07 g cm^{-3}.
74	132	Pospisil, V.	1933	V	21-273	15	60.5	39.5	The above specimen annealed at 300 to 400 C for one week.
75*	132	Pospisil, V.	1933	V	21-273	16	61.4	38.6	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 13.00 g cm^{-3}.
76*	132	Pospisil, V.	1933	V	21-273	16	61.4	38.6	The above specimen annealed at 300 to 400 C for one week.
77*	132	Pospisil, V.	1933	V	21-273	17	62.6	37.4	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 13.16 g cm^{-3}.
78*	132	Pospisil, V.	1933	V	21-273	17	62.6	37.4	The above specimen annealed at 300 to 400 C for one week.
79	132	Pospisil, V.	1933	V	21-273	18	63.6	36.4	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 13.00 g cm^{-3}.
80*	132	Pospisil, V.	1933	V	21-273	18	63.6	36.4	The above specimen annealed at 300 to 400 C for one week.
81*	132	Pospisil, V.	1933	V	21-273	19	64.7	35.3	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 12.93 g cm^{-3}.
82*	132	Pospisil, V.	1933	V	21-273	19	64.7	35.3	The above specimen annealed at 300 to 400 C for one week.
83*	132	Pospisil, V.	1933	V	21-273	20	65.6	34.4	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 13.42 g cm^{-3}.
84*	132	Pospisil, V.	1933	V	21-273	20	65.6	34.4	The above specimen annealed at 300 to 400 C for one week.
85*	132	Pospisil, V.	1933	V	21-273	21	66.5	33.5	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 13.29 g cm^{-3}.
86*	132	Pospisil, V.	1933	V	21-273	21	66.5	33.5	The above specimen annealed at 300 to 400 C for one week.
87*	132	Pospisil, V.	1933	V	21-273	22	67.4	32.6	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 13.60 g cm^{-3}.
88*	132	Pospisil, V.	1933	V	21-273	22	67.4	32.6	The above specimen annealed at 300 to 400 C for one week.
89*	132	Pospisil, V.	1933	V	21-273	23	68.4	31.6	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 13.76 g cm^{-3}.

* Not shown in figure.

TABLE 18. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
90	132	Pospisil, V.	1933	V	21-273	23	68.4	31.6	The above specimen annealed at 300 to 400 C for one week.
91*	132	Pospisil, V.	1933	V	21-273	24	69.7	30.3	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 14.01 g cm^{-3}.
92	132	Pospisil, V.	1933	V	21-273	24	69.7	30.3	The above specimen annealed at 300 to 400 C for one week.
93*	132	Pospisil, V.	1933	V	21-273	25	71.0	29	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 14.18 g cm^{-3}.
94	132	Pospisil, V.	1933	V	21-273	25	71.0	29	The above specimen annealed at 300 to 400 C for one week.
95*	132	Pospisil, V.	1933	V	21-273	26	72.6	27.4	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 14.37 g cm^{-3}.
96*	132	Pospisil, V.	1933	V	21-273	26	72.6	27.4	The above specimen annealed at 300 to 400 C for one week.
97*	132	Pospisil, V.	1933	V	21-273	27	73.8	26.2	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 14.62 g cm^{-3}.
98	132	Pospisil, V.	1933	V	21-273	27	73.8	26.2	The above specimen annealed at 300 to 400 C for one week.
99*	132	Pospisil, V.	1933	V	21-273	28	74.9	25.1	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 14.71 g cm^{-3}.
100*	132	Pospisil, V.	1933	V	21-273	28	74.9	25.1	The above specimen annealed at 300 to 400 C for one week.
101*	132	Pospisil, V.	1933	V	21-273	29	75.6	24.4	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 14.77 g cm^{-3}.
102*	132	Pospisil, V.	1933	V	21-273	29	75.6	24.4	The above specimen annealed at 300 to 400 C for one week.
103*	132	Pospisil, V.	1933	V	21-273	29a	75.6	24.4	Similar to the specimen for Data Set No. 21 but density 14.84 g cm^{-3}.
104	132	Pospisil, V.	1933	V	21-273	29a	75.6	24.4	The above specimen annealed at 300 to 400 C for one week.
105*	132	Pospisil, V.	1933	V	21-273	30	76.4	23.6	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 14.63 g cm^{-3}.
106*	132	Pospisil, V.	1933	V	21-273	30	76.4	23.6	The above specimen annealed at 300 to 400 C for one week.
107*	132	Pospisil, V.	1933	V	21-273	31	77.5	22.5	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 14.88 g cm^{-3}.
108*	132	Pospisil, V.	1933	V	21-273	31	77.5	22.5	The above specimen annealed at 300 to 400 C for one week.
109*	132	Pospisil, V.	1933	V	21-273	32	78.5	21.5	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 15.15 g cm^{-3}.
110	132	Pospisil, V.	1933	V	21-273	32	78.5	21.5	The above specimen annealed at 300 to 400 C for one week.
111*	132	Pospisil, V.	1933	V	21-273	33	79.2	20.8	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 15.32 g cm^{-3}.
112*	132	Pospisil, V.	1933	V	21-273	33	79.2	20.8	The above specimen annealed at 300 to 400 C for one week.
113*	132	Pospisil, V.	1933	V	21-273	34	80.5	19.5	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 15.46 g cm^{-3}.
114	132	Pospisil, V.	1933	V	21-273	34	80.5	19.5	The above specimen annealed at 300 to 400 C for one week.

* Not shown in figure.

TABLE 18. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
115*	132	Pospisil, V.	1933	V	21-273	35	81.7	18.3	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 15.73 g cm^{-3}.
116*	132	Pospisil, V.	1933	V	21-273	35	81.7	18.3	The above specimen annealed at 300 to 400 C for one week.
117*	132	Pospisil, V.	1933	V	21-273	36	82.4	17.6	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 15.85 g cm^{-3}.
118	132	Pospisil, V.	1933	V	21-273	36	82.4	17.6	The above specimen annealed at 300 to 400 C for one week.
119*	132	Pospisil, V.	1933	V	21-273	37	83.3	16.7	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 15.94 g cm^{-3}.
120*	132	Pospisil, V.	1933	V	21-273	37	83.3	16.7	The above specimen annealed at 300 to 400 C for one week.
121*	132	Pospisil, V.	1933	V	21-273	38	84.2	15.8	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 16.17 g cm^{-3}.
122*	132	Pospisil, V.	1933	V	21-273	38	84.2	15.8	The above specimen annealed at 300 to 400 C for one week.
123*	132	Pospisil, V.	1933	V	21-273	39	84.7	15.3	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 16.17 g cm^{-3}.
124	132	Pospisil, V.	1933	V	21-273	39	84.7	15.3	The above specimen annealed at 300 to 400 C for one week.
125*	132	Pospisil, V.	1933	V	21-273	40	85.3	14.7	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 16.31 g cm^{-3}.
126*	132	Pospisil, V.	1933	V	21-273	40	85.3	14.7	The above specimen annealed at 300 to 400 C for one week.
127*	132	Pospisil, V.	1933	V	21-273	41	86.4	13.6	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 16.45 g cm^{-3}.
128*	132	Pospisil, V.	1933	V	21-273	41	86.4	13.6	The above specimen annealed at 300 to 400 C for one week.
129*	132	Pospisil, V.	1933	V	21-273	42	87.4	12.6	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 16.67 g cm^{-3}.
130*	132	Pospisil, V.	1933	V	21-273	42	87.4	12.6	The above specimen annealed at 300 to 400 C for one week.
131*	132	Pospisil, V.	1933	V	21-273	43	88.4	11.6	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 16.80 g cm^{-3}.
132*	132	Pospisil, V.	1933	V	21-273	43	88.4	11.6	The above specimen annealed at 300 to 400 C for one week.
133*	132	Pospisil, V.	1933	V	21-273	44	89.2	10.8	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 16.87 g cm^{-3}.
134*	132	Pospisil, V.	1933	V	21-273	44	89.2	10.8	The above specimen annealed at 300 to 400 C for one week.
135*	132	Pospisil, V.	1933	V	21-273	45	89.9	10.1	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 16.96 g cm^{-3}.
136*	132	Pospisil, V.	1933	V	21-273	45	89.9	10.1	The above specimen annealed at 300 to 400 C for one week.
137*	132	Pospisil, V.	1933	V	21-273	46	90.4	9.6	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 17.03 g cm^{-3}.
138*	132	Pospisil, V.	1933	V	21-273	46	90.4	9.6	The above specimen annealed at 300 to 400 C for one week.

* Not shown in figure.

TABLE 18. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
139*	132	Pospisil, V.	1933	V	21-273	47	90.8	9.2	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 17.20 g cm^{-3}.
140*	132	Pospisil, V.	1933	V	21-273	47	90.8	9.2	The above specimen annealed at 300 to 400 C for one week.
141	132	Pospisil, V.	1933	V	21-273	48	91.3	8.7	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 17.26 g cm^{-3}.
142*	132	Pospisil, V.	1933	V	21-273	48	91.3	8.7	The above specimen annealed at 300 to 400 C for one week.
143*	132	Pospisil, V.	1933	V	21-273	49	92.0	8.0	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 17.49 g cm^{-3}.
144*	132	Pospisil, V.	1933	V	22-273	49	92.0	8.0	The above specimen annealed at 300 to 400 C for one week.
145*	132	Pospisil, V.	1933	V	21-273	50	92.6	7.4	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 17.64 g cm^{-3}.
146*	132	Pospisil, V.	1933	V	21-273	50	92.6	7.4	The above specimen annealed at 300 to 400 C for one week.
147*	132	Pospisil, V.	1933	V	21-273	51	93.1	6.9	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 17.64 g cm^{-3}.
148*	132	Pospisil, V.	1933	V	21-273	51	93.1	6.9	The above specimen annealed at 300 to 400 C for one week.
149	132	Pospisil, V.	1933	V	21-273	52	93.7	6.3	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 17.71 g cm^{-3}.
150*	132	Pospisil, V.	1933	V	21-273	52	93.7	6.3	The above specimen annealed at 300 to 400 C for one week.
151*	132	Pospisil, V.	1933	V	21-273	53	94.6	5.4	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 17.89 g cm^{-3}.
152*	132	Pospisil, V.	1933	V	21-273	53	94.6	5.4	The above specimen annealed at 300 to 400 C for one week.
153	132	Pospisil, V.	1933	V	21-273	54	96.6	3.4	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 18.35 g cm^{-3}.
154*	132	Pospisil, V.	1933	V	21-273	54	96.6	3.4	The above specimen annealed at 300 to 400 C for one week.
155*	132	Pospisil, V.	1933	V	21-273	55	98.3	1.7	4 mm diameter x 6 cm long; quenched in ice-water from 500 C; density 18.85 g cm^{-3}.
156	132	Pospisil, V.	1933	V	21-273	55	98.3	1.7	The above specimen annealed at 300 to 400 C for one week.
157*	134	Davis, T.H. and Rayne, J.A.	1972		4.2-295		82.3	17.7	Calculated composition (60.0 a/o Au); 1.25 x 0.100 x 0.100 in.; prepared from 99.999+ pure gold and 99.9999 pure copper by induction melting; heat-treated at 425 C.
158*	135	Huray, P.G., Roberts, L.D., and Thomson, J.D.	1971		4.2		50.82	49.18	Calculated composition (25 a/o Au); foil specimen 0.001 in. thick; prepared from 99.99 pure Cu and Au by arc-melting in argon and drop-casting in a cylindrical mold, alloy cylinder annealed in an inert atmosphere for 5 days within 50 C of the melting point, cut lengthwise and rolled with intermittent annealing; heat-treated at 368 C for 100 hr, furnace-cooled to 250 C, maintained for 120 hr and quenched in water at room temperature; ordered.
159*	135	Huray, P.G., et al.	1971		4.2-296		50.82	49.18	The above specimen annealed in vacuum at 410 C for 30 min and quenched in vacuum-pump oil at room temperature.

* Not shown in figure.

TABLE 18. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
160*	135	Huray, P.G., Roberts, L.D., and Thomson, J.D.	1971		4.2-296		50.82	49.18	The above specimen quenched from 450 C.
161*	135	Huray, P.G., et al.	1971		4.2-296		50.82	49.18	The above specimen quenched from 500 C.
162	135	Huray, P.G., et al.	1971		4.2-296		50.82	49.18	The above specimen quenched from 600 C; disordered.
163*	135	Huray, P.G., et al.	1971		4.2-296		50.82	49.18	The above specimen quenched from 700 C; disordered.
164*	135	Huray, P.G., et al.	1971		4.2-296		50.82	49.18	The above specimen quenched from 800 C; disordered.
165	136	Ascoli, A., Bergamini, P., and Queirolo, G.T.	1972		297-1311			0.32	Calculated composition (1.0 a/o Cu); 0.25 cm diameter x 10 cm long; prepared from 99.9995 pure Au and 99.999 pure Cu.
166	136	Ascoli, A., et al.	1972		301-1317			0.16	Calculated composition (0.5 a/o Cu); similar to the above specimen.
167	127	Roll, A. and Motz, H.	1957	R	1273-1473		50.8	49.2	Calculated composition (25 a/o Au); in liquid state; prepared from electrolytic copper and 99.95 pure gold; $d\rho/dT = 0.0091\ \mu\Omega\ cm\ K^{-1}$.
168*	127	Roll, A. and Motz, H.	1957	R	1273-1473		54.7	45.3	Calculated composition (28 a/o Au); similar to the above specimen but $d\rho/dT = 0.0093\ \mu\Omega\ cm\ K^{-1}$.
169	127	Roll, A. and Motz, H.	1957	R	1273-1473		57.1	42.9	Calculated composition (30 a/o Au); similar to the above specimen but $d\rho/dT = 0.0089\ \mu\Omega\ cm\ K^{-1}$.
170*	127	Roll, A. and Motz, H.	1957	R	1273-1473		59.3	40.7	Calculated composition (32 a/o Au); similar to the above specimen but $d\rho/dT = 0.0109\ \mu\Omega\ cm\ K^{-1}$.
171*	127	Roll, A. and Motz, H.	1957	R	1273-1473		61.5	38.5	Calculated composition (34 a/o Au); similar to the above specimen but $d\rho/dT = 0.0104\ \mu\Omega\ cm\ K^{-1}$.
172	127	Roll, A. and Motz, H.	1957	R	1273-1473		67.4	32.6	Calculated composition (40 a/o Au); similar to the above specimen but $d\rho/dT = 0.0096\ \mu\Omega\ cm\ K^{-1}$.
173	127	Roll, A. and Motz, H.	1957	R	1273-1473		75.6	24.4	Calculated composition (50 a/o Au); similar to the above specimen but $d\rho/dT = 0.0118\ \mu\Omega\ cm\ K^{-1}$.
174*	127	Roll, A. and Motz, H.	1957	R	1273-1473		82.3	17.7	Calculated composition (60 a/o Au); similar to the above specimen but $d\rho/dT = 0.0107\ \mu\Omega\ cm\ K^{-1}$.
175*	127	Roll, A. and Motz, H.	1957	R	1273-1473		86.1	13.9	Calculated composition (66.7 a/o Au); similar to the above specimen but $d\rho/dT = 0.0120\ \mu\Omega\ cm\ K^{-1}$.
176*	127	Roll, A. and Motz, H.	1957	R	1273-1473		87.2	12.8	Calculated composition (68.7 a/o Au); similar to the above specimen but $d\rho/dT = 0.0136\ \mu\Omega\ cm\ K^{-1}$.
177*	127	Roll, A. and Motz, H.	1957	R	1273-1473		87.9	12.1	Calculated composition (70 a/o Au); similar to the above specimen but $d\rho/dT = 0.0124\ \mu\Omega\ cm\ K^{-1}$.
178*	127	Roll, A. and Motz, H.	1957	R	1273-1473		88.9	11.1	Calculated composition (72 a/o Au); similar to the above specimen but $d\rho/dT = 0.0115\ \mu\Omega\ cm\ K^{-1}$.
179*	127	Roll, A. and Motz, H.	1957	R	1273-1473		90.3	9.7	Calculated composition (75 a/o Au); similar to the above specimen but $d\rho/dT = 0.0134\ \mu\Omega\ cm\ K^{-1}$.

* Not shown in figure.

TABLE 18. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Cu	Composition (continued), Specifications, and Remarks
180*	127	Roll, A. and Motz, H.	1957	R	1273-1473		91.2	8.8	Calculated composition (77 a/o Au); similar to the above specimen.
181*	127	Roll, A. and Motz, H.	1957	R	1273-1473		95.6	4.4	Calculated composition (87.5 a/o Au); similar to the above specimen but $d\rho/dT = 0.0153\ \mu\Omega\ cm\ K^{-1}$.
182	137	Damon, D.H., Mathur, M.P., and Klemens, P.G.	1968	A	10.1-40.0			0.0085	Wire specimen diameter 0.7 to 0.025 cm and about 20 cm long, annealed at 750 K from 8 to 24 h; loosely wound on 1.5 cm diameter lava sample holder; residual resistivity 1.136 $\mu\Omega$ cm.

* Not shown in figure.

TABLE 19. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

T	ρ
DATA SET 1*	
289.2	6.71
477.2	8.63
511.2	8.97
569.2	9.63
595.2	10.22
621.2	11.27
629.2	11.49
658.2	13.77
661.2	14.24
663.2	14.90
666.2	15.08
671.2	15.09
680.2	15.11
685.2	15.19
692.2	15.24
700.2	15.29
708.2	15.29
710.[illegible]	15.35
716.2	15.38
723.2	15.41
DATA SET 2*	
283.2	6.90
418.2	8.23
590.2	10.71
597.2	10.86
604.2	11.22
630.2	12.21
633.2	12.47
638.2	12.83
642.2	13.10
645.2	13.44
646.2	13.75
648.2	14.01
651.2	14.62
656.2	14.98
666.2	15.08
671.2	15.09
680.2	15.11
685.2	15.19
692.2	15.24
700.2	15.29
708.2	15.29
710.2	15.38
716.2	15.38
723.2	15.41

T	ρ
DATA SET 3*	
277.2	12.08
284.2	12.14
493.2	13.71
510.2	13.83
521.2	13.86
529.2	13.91
539.2	13.97
551.2	14.07
560.2	14.15
571.2	14.14
579.2	14.12
589.2	13.92
595.2	13.80
601.2	13.69
611.2	13.57
618.2	13.57
631.2	13.41
656.2	13.21
DATA SET 4*	
391.2	8.81
424.2	9.13
463.2	9.58
499.2	9.92
531.2	10.24
561.2	10.69
590.2	11.36
600.2	11.68
605.2	11.70
612.2	12.12
620.2	12.34
625.2	12.55
634.2	12.91
641.2	13.19
647.2	13.53
653.2	13.99
661.2	14.94
662.2	15.50
662.2	15.74
664.2	15.90
674.2	15.95
685.2	16.02
696.2	16.08
705.2	16.10
713.2	16.15
723.2	16.20
732.2	16.23

T	ρ
DATA SET 5*	
282.2	7.68
593.2	11.82
607.2	12.30
625.2	13.20
628.2	13.40
631.2	13.61
634.2	13.89
646.2	14.77
648.2	14.92
653.2	15.39
655.2	15.59
656.2	15.85
664.2	15.90
674.2	15.95
685.2	16.02
696.2	16.08
705.2	16.10
713.2	16.15
723.2	16.20
732.2	16.23
DATA SET 6*	
287.2	10.24
494.2	12.30
527.2	12.55
542.2	12.72
578.2	13.21
587.2	13.41
597.2	13.73
604.2	13.88
612.2	14.16
617.2	14.34
624.2	14.57
630.2	14.69
631.2	14.84
638.2	14.99
639.2	15.12
646.2	15.52
648.2	15.72
651.2	15.89
657.2	15.91
664.2	15.91
669.2	16.02
675.2	16.02
694.2	16.10
700.2	16.13

T	ρ
DATA SET 7*	
283.2	9.40
599.2	13.28
619.2	14.79
622.2	14.96
628.2	15.16
637.2	15.68
640.2	15.86
644.2	15.86
651.2	15.89
657.2	15.91
664.2	15.91
669.2	16.02
675.2	16.02
694.2	16.10
700.2	16.17
DATA SET 8*	
283.2	10.49
327.2	11.01
593.2	14.56
630.2	15.06
640.2	15.19
646.2	15.36
650.2	15.49
655.2	15.67
660.2	16.01
666.2	16.25
669.2	16.63
673.2	17.11
673.2	18.00
674.2	19.57
683.2	20.37
691.2	20.46
697.2	20.47
701.2	20.57
707.2	20.63
DATA SET 9*	
286.2	9.79
628.2	15.69
630.2	16.00
632.2	16.22
632.2	16.53
634.2	17.10
634.2	18.20

T	ρ
DATA SET 9 (cont.)*	
635.2	18.92
636.2	19.48
640.2	19.90
646.2	20.00
651.2	20.14
654.2	20.14
660.2	20.18
667.2	20.29
683.2	20.37
691.2	20.46
697.2	20.47
701.2	20.57
707.2	20.63
DATA SET 10*	
18	13.86
48	14.38
88	14.65
122	14.95
147	15.16
173	15.31
193	15.61
210	15.73
230	15.85
242	15.85
256	15.61
267	15.33
278	15.24
284	14.99
294	14.67
301	14.40
309	14.03
319	13.55
327	12.87
DATA SET 11*	
15	7.32
76	8.21
100	8.50
132	8.79
153	9.17
170	9.34
182	9.57
198	9.80
218	9.91

T	ρ
DATA SET 11 (cont.)*	
230	10.06
253	10.36
275	10.83
294	11.11
322	12.18
327	12.87
DATA SET 12*	
15	7.35
74	6.14
101	8.53
131	8.82
152	9.24
170	9.32
183	9.59
198	9.81
218	9.91
230	10.06
238	10.18
253	10.36
268	10.57
281	10.72
294	11.11
305	11.17
310	11.26
328	11.38
344	11.74
369	12.00
386	12.53
393	12.68
403	13.77
413	14.74
419	15.92
DATA SET 13*	
17	6.80
139	8.20
226	9.28
277	10.17
311	10.98
330	11.79
354	12.67
381	13.94
400	14.76
419	15.87

* Not shown in figure.

TABLE 19. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

DATA SET 14*

T	ρ
17	6.80
139	8.20
226	9.28
277	10.17
329	11.39
343	11.71
355	12.08
359	12.22
374	12.36
382	11.91
389	12.11
393	12.40
401	12.72
408	13.14
410	13.59
414	14.08
419	15.23
423	16.13
426	16.52
427	17.07
427	17.59

DATA SET 15*

T	ρ
404	15.43
414	16.46
416	16.85
420	17.28
427	17.59

DATA SET 16*

T	ρ
448	20.80
453	20.90
458	21.05
467	21.22

DATA SET 17*

T	ρ
10	6.11
23	6.31
110	7.50
150	7.99
196	8.49
225	8.82
239	9.42
275	9.68
284	9.79

DATA SET 17 (cont.)*

T	ρ
291	10.01
300	10.17
305	10.21
309	10.51
322	10.76
335	11.19
348	11.83
355	12.09
360	12.20
365	12.59
369	12.90
377	13.30
385	14.23
391	15.36
394	15.81
394	16.87
396	18.85
398	20.36
401	20.56
408	20.65
414	20.58
419	20.73
426	20.60
433	20.80
440	20.80
448	20.80

DATA SET 18*

T	ρ
10	6.11
23	6.31
110	7.50
150	7.99
196	8.49
225	8.82
259	9.42
275	9.68
281	9.79
291	10.01
300	10.17
314	10.40
331	10.76
339	11.06
347	11.35
357	11.75
370	11.98
379	12.17

DATA SET 19*

T	ρ
100	6.91
141	7.45
203	8.21
239	8.55
262	9.01
281	9.43
297	9.61
314	10.04
335	10.55
343	10.86
349	11.17
363	11.63
379	12.17

DATA SET 20*

T	ρ
293	4.3

DATA SET 21*

T	ρ
290	8.58
443	10.51
515	11.52
534	11.96
563	12.73
581	13.16
592	13.41
604	13.83
625	14.50
630	14.80
635	15.06
640	15.37
647	15.37
654	16.16
658	16.45
661	16.77
662	17.20
664	19.00
667	19.77
673	19.82
680	19.92
690	19.96
700	20.00
710	20.26
723	20.32

DATA SET 22*

T	ρ
290	8.58
443	10.51
515	11.52
534	11.96
563	12.73
581	13.16
592	13.41
604	13.83
633	17.59
634	19.45
641	19.59
645	19.63
651	19.67
659	19.77
667	19.77
673	19.82
680	19.92
690	19.96
700	20.00
710	20.26
723	20.32

DATA SET 23

T	ρ
4.5	9.388
5.8	9.388
7.3	9.389
8.6	9.389
10.8	9.390
13.4	9.392
15.2	9.393
17.7	9.398*
21.1	9.404*
24.0	9.411
27.2	9.422*
30.5	9.437
34.3	9.456*
37.6	9.475*
43.7	9.513
49.8	9.553*
55.2	9.593
61.0	9.638*
65.3	9.671*
70.2	9.714
74.5	9.750*
79.6	9.792*
83.6	9.828*
89.3	9.877

DATA SET 24

T	ρ
4.0	1.224
5.5	1.224
7.1	1.224
8.4	1.225
11.9	1.226
14.5	1.228*
16.3	1.231
18.5	1.238*
21.3	1.246
23.3	1.255*
26.0	1.269*
27.9	1.283*
29.9	1.297*
31.8	1.312
32.8	1.325*
35.9	1.355*
37.5	1.369*
39.0	1.382*
40.5	1.399
41.9	1.412*
46.7	1.472*
47.7	1.483*
50.4	1.518
52.3	1.540*
56.7	1.596*
61.0	1.655
66.1	1.726*
71.5	1.804
76.8	1.881*
80.6	1.935*
86.5	2.019

DATA SET 25

T	ρ
5.3	11.51
7.4	11.51
9.0	11.51
10.7	11.51*
11.2	11.52
13.7	11.52*
16.0	11.53
18.4	11.53*
21.8	11.55*
26.2	11.57
27.8	11.58*
31.0	11.60
34.6	11.63*
38.5	11.66*

DATA SET 25 (cont.)

T	ρ
44.4	11.72
50.1	11.77*
55.0	11.82
60.9	11.88*
70.4	11.97
75.1	12.02*
79.9	12.06*
84.4	12.10

DATA SET 26

T	ρ
3.6	0.663
5.5	0.663
11.3	0.666
13.8	0.670*
16.8	0.677
20.6	0.692
23.7	0.713*
27.3	0.737*
30.0	0.756
34.5	0.789
37.9	0.824*
42.2	0.866
48.0	0.929
53.6	0.994
58.2	1.043
63.7	1.109*
68.7	1.167
74.3	1.239*
78.8	1.297
82.9	1.346*
89.2	1.420

DATA SET 27

T	ρ
293.2	0.82
373.2	0.98
423.2	1.06
473.2	1.18
523.2	1.35
573.2	1.53
623.2	1.79
673.2	2.20

DATA SET 28

T	ρ
273	6.99
373	7.46

* Not shown in figure.

TABLE 19. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 29	
273	11.76
373	12.20
DATA SET 30	
273	15.87
373	16.95
DATA SET 31	
273	18.8
373	20.0
DATA SET 32	
273	20.00
373	21.74
DATA SET 33*	
83	9.27
DATA SET 34*	
273	10.88
DATA SET 35	
22	3.828
83	4.345
273	5.940
DATA SET 36	
22	1.841
63	2.353
273	3.930
DATA SET 37*	
83	6.64
DATA SET 38*	
83	3.23
273	5.80

T	ρ
DATA SET 39*	
83	3.126
273	5.420
DATA SET 40*	
273	11.49
DATA SET 41*	
83	9.88
273	11.48
DATA SET 42*	
22	2.70
83	3.41
DATA SET 43	
83	11.57
273	13.20
292	13.41
DATA SET 44	
83	1.753
273	3.974
293	4.820
DATA SET 45*	
83	2.228
273	4.480
DATA SET 46*	
83	1.797
273	4.070
DATA SET 47*	
83	9.17
DATA SET 48*	
83	7.90

T	ρ
DATA SET 49*	
83	1.826
273	4.090
DATA SET 50*	
291.2	11.31
DATA SET 51*	
291.2	5.67
DATA SET 52*	
291.2	11.24
DATA SET 53*	
291.2	5.34
DATA SET 54*	
291.2	13.82
DATA SET 55*	
291.2	4.20
DATA SET 56*	
291.2	11.03
DATA SET 57*	
291.2	10.88
DATA SET 58*	
291.2	10.96
DATA SET 59	
20.8	9.62
78.2	9.98
273.2	11.49

T	ρ
DATA SET 60*	
20.8	1.85
78.2	2.46
273.2	4.86
DATA SET 61*	
20.8	9.33
78.2	9.71
273.2	11.22
DATA SET 62	
20.8	1.37
78.2	1.97
273.2	4.34
DATA SET 63*	
20.8	9.87
78.2	10.27
273.2	11.85
DATA SET 64*	
20.8	1.63
78.2	2.25
273.2	4.71
DATA SET 65	
20.8	9.98
78.2	10.37
273.2	11.92
DATA SET 66	
20.8	2.63
78.2	3.23
273.2	5.58
DATA SET 67	
20.8	10.42
78.2	10.82
273.2	12.36

T	ρ
DATA SET 68*	
20.8	3.89
78.2	4.48
273.2	6.78
DATA SET 69*	
20.8	10.93
78.2	11.35
273.2	12.97
DATA SET 70	
20.8	5.29
78.2	5.89
273.2	8.21
DATA SET 71*	
20.8	11.14
78.2	11.56
273.2	13.18
DATA SET 72	
20.8	7.89
78.2	8.48
273.2	10.66
DATA SET 73*	
20.8	10.75
78.2	11.16
273.2	12.72
DATA SET 74	
20.8	8.48
78.2	9.05
273.2	11.07
DATA SET 75*	
20.8	11.10
78.2	11.56
273.2	13.19

T	ρ
DATA SET 76*	
20.8	9.75
78.2	10.30
273.2	12.27
DATA SET 77*	
20.8	11.11
78.2	11.56
273.2	13.18
DATA SET 78*	
20.8	10.19
78.2	10.72
273.2	12.58
DATA SET 79	
20.8	11.70
78.2	12.17
273.2	13.86
DATA SET 80*	
20.8	11.12
78.2	11.63
273.2	13.48
DATA SET 81*	
20.8	11.65
78.2	12.10
273.2	13.73
DATA SET 82*	
20.8	11.42
78.2	11.93
273.2	13.80
DATA SET 83*	
20.8	11.29
78.2	11.74
273.2	13.30

* Not shown in figure.

TABLE 19. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
DATA SET 84*		DATA SET 92		DATA SET 100*		DATA SET 108*		DATA SET 116*		DATA SET 124	
20.8	9.24	20.8	5.97	20.8	1.48	20.8	1.96	20.8	6.15	20.8	10.50
78.2	9.74	78.2	6.50	78.2	2.09	78.2	2.58	78.2	6.70	78.2	11.06
273.2	11.61	273.2	8.55	273.2	4.28	273.2	4.79	273.2	8.69	273.2	12.90
DATA SET 85*		DATA SET 93*		DATA SET 101*		DATA SET 109*		DATA SET 117*		DATA SET 125*	
20.8	11.98	20.8	12.10	20.8	12.29	20.8	11.66	20.8	11.02	20.8	10.42
78.2	12.45	78.2	12.54	78.2	12.75	78.2	12.12	78.2	11.53	78.2	10.92
273.2	14.08	273.2	14.13	273.2	14.37	273.2	13.74	273.2	13.23	273.2	12.61
DATA SET 86*		DATA SET 94		DATA SET 102*		DATA SET 110		DATA SET 118		DATA SET 126*	
20.8	8.41	20.8	4.17	20.8	1.65	20.8	2.73	20.8	6.86	20.8	10.45
78.2	8.94	78.2	4.75	78.2	2.28	78.2	3.33	78.2	7.41	78.2	10.99
273.2	10.95	273.2	6.91	273.2	4.58	273.2	5.49	273.2	9.38	273.2	12.76
DATA SET 87*		DATA SET 95*		DATA SET 103*		DATA SET 111*		DATA SET 119*		DATA SET 127*	
20.8	11.39	20.8	11.92	20.8	11.99	20.8	11.97	20.8	10.97	20.8	10.18
78.2	11.84	78.2	12.34	78.2	12.44	78.2	12.44	78.2	11.47	78.2	10.69
273.2	13.40	273.2	13.93	273.2	14.03	273.2	14.10	273.2	13.09	273.2	12.40
DATA SET 88*		DATA SET 96*		DATA SET 104		DATA SET 112*		DATA SET 120*		DATA SET 128*	
20.8	8.11	20.8	3.89	20.8	0.93	20.8	3.96	20.8	7.16	20.8	10.25
78.2	8.61	78.2	4.41	78.2	1.56	78.2	4.57	78.2	7.70	78.2	10.78
273.2	10.53	273.2	6.42	273.2	3.83	273.2	6.82	273.2	9.65	273.2	12.53
DATA SET 89*		DATA SET 97*		DATA SET 105*		DATA SET 113*		DATA SET 121*		DATA SET 129*	
20.8	11.38	20.8	12.05	20.8	12.09	20.8	12.14	20.8	10.60	20.8	9.73
78.2	11.82	78.2	12.49	78.2	12.52	78.2	12.67	78.2	11.12	78.2	10.24
273.2	13.37	273.2	14.08	273.2	14.11	273.2	14.49	273.2	12.80	273.2	11.97
DATA SET 90		DATA SET 98		DATA SET 106*		DATA SET 114		DATA SET 122*		DATA SET 130*	
20.8	7.17	20.8	1.43	20.8	1.28	20.8	4.78	20.8	10.52	20.8	9.85
78.2	7.67	78.2	2.05	78.2	1.89	78.2	5.34	78.2	11.08	78.2	10.37
273.2	9.60	273.2	4.25	273.2	4.12	273.2	7.36	273.2	12.91	273.2	12.10
DATA SET 91*		DATA SET 99*		DATA SET 107*		DATA SET 115*		DATA SET 123*		DATA SET 131*	
20.8	11.37	20.8	11.96	20.8	11.72	20.8	11.28	20.8	10.63	20.8	9.30
78.2	11.84	78.2	12.39	78.2	12.18	78.2	11.75	78.2	11.14	78.2	9.81
273.2	13.39	273.2	13.95	273.2	13.78	273.2	13.37	273.2	12.85	273.2	11.58

* Not shown in figure.

TABLE 19. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 132*	
20.8	9.43
78.2	9.94
273.2	11.66
DATA SET 133*	
20.8	9.19
78.2	9.71
273.2	11.47
DATA SET 134*	
20.8	9.29
78.2	9.79
273.2	11.50
DATA SET 135*	
20.8	8.84
78.2	9.37
273.2	11.14
DATA SET 136*	
20.8	8.94
78.2	9.45
273.2	11.15
DATA SET 137*	
20.8	8.67
78.2	9.21
273.2	10.99
DATA SET 138*	
20.8	8.73
78.2	9.24
273.2	10.95
DATA SET 139*	
20.8	8.23
78.2	8.76
273.2	10.52
DATA SET 140*	
20.8	8.26
78.2	8.76
273.2	10.46

T	ρ
DATA SET 141	
20.8	8.03
78.2	8.51
273.2	10.22
DATA SET 142*	
20.8	8.08
78.2	8.58
273.2	10.28
DATA SET 143*	
20.8	7.23
78.2	7.74
273.2	9.47
DATA SET 144*	
20.8	7.25
78.2	7.75
273.2	9.45
DATA SET 145*	
20.8	6.96
78.2	7.46
273.2	9.18
DATA SET 146*	
20.8	6.84
78.2	7.33
273.2	9.01
DATA SET 147*	
20.8	6.95
78.2	7.45
273.2	9.15
DATA SET 148*	
20.8	6.94
78.2	7.44
273.2	9.13
DATA SET 149	
20.8	6.67
78.2	7.17
273.2	8.90

T	ρ
DATA SET 150*	
20.8	6.58
78.2	7.08
273.2	8.76
DATA SET 151*	
20.8	6.01
78.2	6.52
273.2	8.24
DATA SET 152*	
20.8	5.98
78.2	6.48
273.2	8.20
DATA SET 153	
20.8	4.01
78.2	4.49
273.2	6.16
DATA SET 154*	
20.8	3.99
78.2	4.48
273.2	6.14
DATA SET 155*	
20.8	2.06
78.2	2.55
273.2	4.20
DATA SET 156	
20.8	2.05
78.2	2.54
273.2	4.17
DATA SET 157*	
4.2	11.194
77	11.675
295	13.523
DATA SET 158*	
4.2	0.970

T	ρ
DATA SET 159*	
4.2	9.271
78	9.626
296	11.28
DATA SET 160*	
4.2	9.248
78	9.612
296	11.22
DATA SET 161*	
4.2	9.260
78	9.615
296	11.26
DATA SET 162	
4.2	9.308
78	9.683
296	11.35
DATA SET 163*	
4.2	9.286
78	9.652
296	11.34
DATA SET 164*	
4.2	9.320
78	9.687
296	11.34
DATA SET 165	
297	2.522
478	4.059
607	5.227
713	6.226
736	6.453
768	6.767
783	6.920
821	7.314
844	7.556
864	7.766
885	7.987
906	8.218
916	8.325
975	8.986
1017	9.477

T	ρ
DATA SET 165 (cont.)	
1051	9.863
1081	10.26
1109	10.61
1169	11.38
1209	11.93
1241	12.38
1281	12.96
1311	13.41
DATA SET 166	
301	2.736
386	3.418
483	4.226
508	4.449
583	5.132
611	5.367
637	5.607
702	6.235
725	6.459
745	6.663
783	7.038
799	7.204
810	7.310
833	7.548
846	7.681
855	7.778
869	7.929
881	8.055
889	8.136
952	8.836
983	9.178
1021	9.619
1054	10.02
1077	10.30
1114	10.77
1143	11.13
1183	11.66
1214	12.10
1260	12.76
1289	13.20
1317	13.64
DATA SET 167	
1273	29.9
1373	30.8
1473	31.7

T	ρ
DATA SET 168*	
1273	30.3
1373	31.3
1473	32.1
DATA SET 169	
1273	31.8
1373	32.6
1473	33.5
DATA SET 170*	
1273	31.9
1373	32.9
1473	34.0
DATA SET 171*	
1273	31.9
1373	32.9
1473	33.8
DATA SET 172	
1273	33.3
1373	34.3
1473	35.2
DATA SET 173	
1273	34.2
1373	35.4
1473	36.5
DATA SET 174*	
1273	34.3
1373	35.4
1473	36.4
DATA SET 175*	
1273	33.6
1373	34.9
1473	36.0
DATA SET 176*	
1273	33.9
1373	35.4
1473	36.7

* Not shown in figure.

TABLE 19. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD + COPPER ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 177*	
1273	34.1
1373	35.3
1473	36.5
DATA SET 178*	
1273	34.4
1373	35.6
1473	36.8
DATA SET 179*	
1273	33.8
1373	35.2
1473	36.5
DATA SET 180*	
1273	33.5
1373	34.9
1473	36.2
DATA SET 181*	
1273	32.0
1373	33.5
1473	35.0
DATA SET 182	
10.1	1.1374
11.1	1.1381
12.1	1.1391
12.9	1.1404
14.0	1.1421
14.9	1.1441
16.0	1.1464
17.0	1.1490
17.9	1.1521
19.9	1.1594
25.0	1.1845
30.0	1.2162
35.0	1.2540
40.0	1.2945

* Not shown in figure.

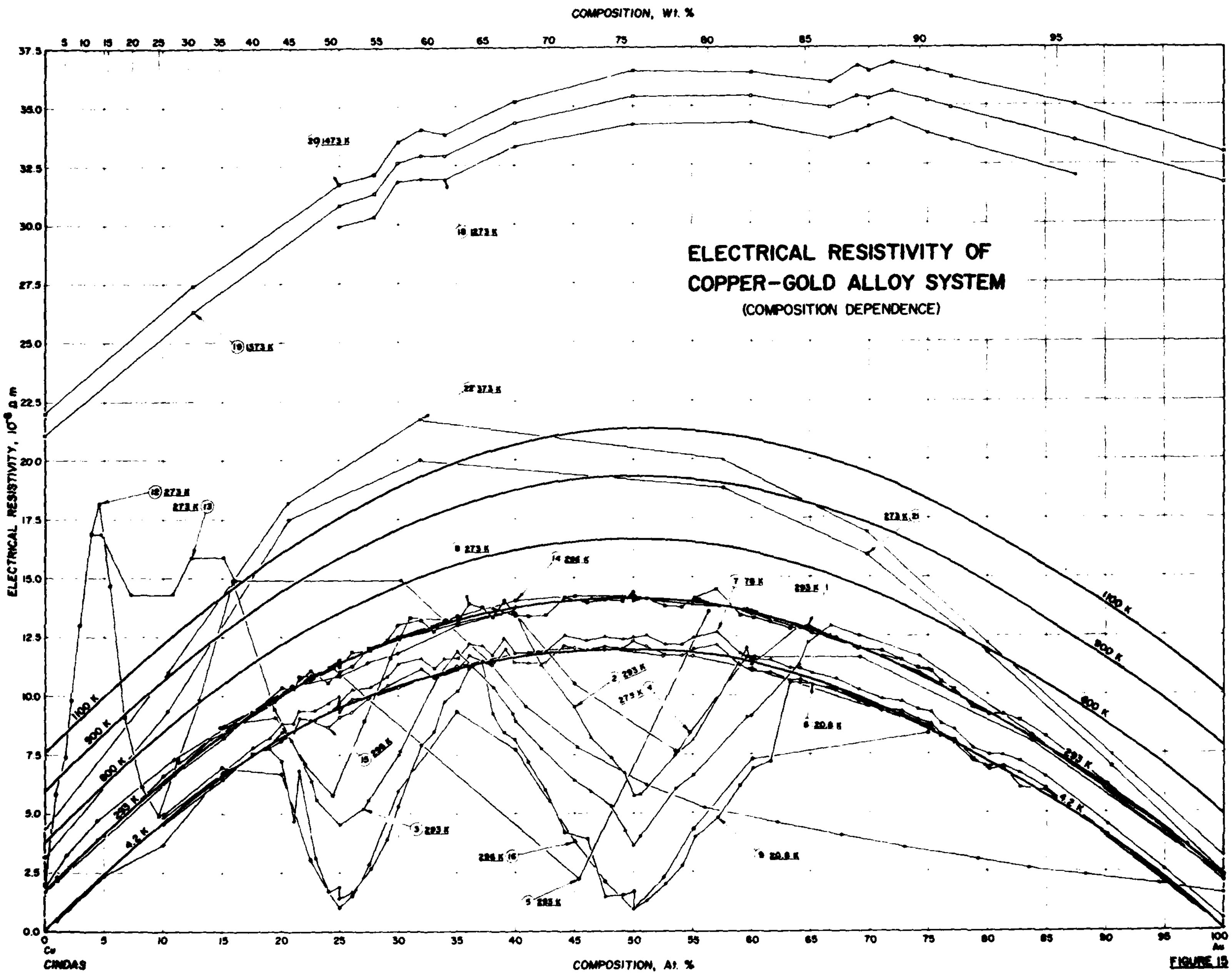

ELECTRICAL RESISTIVITY OF
COPPER-GOLD ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION, Wt. %
COMPOSITION, At. %
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
CINDAS
1100 K
900 K
600 K
293 K
4.2 K

FIGURE 15

TABLE 20. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER-GOLD ALLOY SYSTEM (Composition Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Au)	Composition (weight percent), Specifications, and Remarks
1	122	Johansson, C.H. and Linde, J.D.	1936		293.2	4.4-97	Alloys quenched from 923 K.
2	122	Johansson, C.H. and Linde, J.D.	1936		293.2	38-64	Alloys furnace-cooled.
3	122	Johansson, C.H. and Linde, J.D.	1936		293.2	0-100	Alloys annealed at 473 K.
4	138	Sedström, E.	1924		273.2	0-100	Specimens rolled and drawn to 1 mm^2 in cross-section and 3 cm long; annealed close to melting point for 30 min.
5	139	Eitel-McCullough, Inc.	1963		293.2		0.010 in. thick wire specimens; measured at room temperature, assigned as 20 C.
6	132	Pospisil, V.	1933		20.8	10-100	4 mm diameter x 6 cm long; quenched in ice water from 773 K.
7	132	Pospisil, V.	1933		78.2	10-100	The above specimens.
8	132	Pospisil, V.	1933		273.2	10-100	The above specimens.
9	132	Pospisil, V.	1933		20.8	10-100	The above specimens annealed at 573 to 673 K for one week.
10*	132	Pospisil, V.	1933		78.2	10-100	The above specimens.
11*	132	Pospisil, V.	1933		273.2	10-100	The above specimens.
12	140	Broniewski, W. and Wesolowski, K.	1934		273.2	0-34	Prepared in graphite crucible in high frequench furnace, homogenized for 50 h at 1073 K, then drawn to 5 mm diameter; heated for 1 h at 923 K and quenched in water; data extracted from smoothed curve.
13	140	Broniewski, W. and Wesolowski, K.	1934		273.2	0-100	Similar to the above specimens, but cooled slowly to 573 K over a period of 50 h rather than quenched.
14	135	Huray, P.G., Roberts, L.D., and Thomson, J.D.	1971		296.2	1.0-75	Foil specimens 0.001 in. thick; prepared from 99.99 pure metals by arc-melting in argon atmosphere, drop-casting into a cylindrical mold, obtained cylindrical alloys annealed in an inert atmosphere within 50 K of the melting points for 5 days, cut lengthwise and rolled with intermittent annealing; heat-treated in vacuum at 873 K for 30 min. and quenched in vacuum pump oil at room temperature.
15	135	Huray, P.G., et al.	1971		4.2	1.0-75	The above specimens.
16	135	Huray, P.G., et al.	1971		4.2	10-75	The above specimens annealed in argon at 641 K for 100 h, furnace-cooled to 523 K, maintained for 120 h, then quenched in water at room temperature.
17*	141	Lengeler, B., Schilling, W., and Wenzl, H.	1970	V	4.2	0.08-1.8	Wire specimens 150 to 270 μm thick and about 30 cm long; supplied by DEGUSSA.
18	127	Roll, A. and Motz, H.	1957	R	1273	25-88	Specimens prepared from electrolytic copper and 99.95 pure gold; in liquid state; reported error ±1%.
19	127	Roll, A. and Motz, H.	1957	R	1373	0-100	The above specimens.
20	127	Roll, A. and Motz, H.	1957	R	1473	0-100	The above specimens.
21	130	Sedström, E.	1919		273.2	0-100	Wire specimens 1 mm in diameter; rolled and drawn; annealed at near melting point for 30 min.
22	130	Sedström, E.	1919		373.2	0-100	The above specimens.

* Not shown in figure.

TABLE 21. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER-*GOLD* ALLOY SYSTEM (Composition Dependence)

[Composition, C, a/o Au; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

C	ρ	C	ρ	C	ρ	C	ρ	C	ρ	C	ρ
DATA SET 1 (T = 293.2 K)		DATA SET 3 (T = 293.2 K)		DATA SET 4 (cont.) (T = 273.2 K)		DATA SET 6 (cont.) (T = 20.8 K)		DATA SET 7 (T = 78.2 K)		DATA SET 7 (cont.) (T = 78.2 K)	
4.4	3.87	0.00	1.70	20.9	10.4	35.05	11.11	10.00	4.85	71.07	9.81
10.9	6.73	10.9	6.70	25.0	10.8	36.03	11.70	15.01	6.76	72.70	9.71
14.0	8.15	14.0	8.17	27.4	11.4	37.14	11.65	17.51	7.81	74.16	9.37
16.0	8.67	16.0	8.83	30.0	11.8	38.07	11.29	18.93	8.20	75.22	9.21
19.5	9.75	19.5	9.07	35.1	13.0	39.02	11.98	20.01	8.80	76.09	8.76
22.6	10.88	20.9	8.10	39.8	13.6	39.99	11.39	21.07	8.85	77.19	8.51
25.0	11.35	22.6	8.37	45.0	10.5	41.10	11.38	21.55	9.37	78.76	7.74
26.0	11.58	23.0	5.58	53.5	7.6	42.58	11.37	22.93	9.37	80.14	7.46
30.1	12.40	25.0	4.49	53.7	7.6	44.11	12.10	24.08	9.66	81.31	7.45
35.1	13.10	27.0	5.19	54.7	8.4	46.07	11.92	24.98	9.98	82.74	7.17
39.8	13.57	27.4	5.53	59.6	11.6	47.59	12.05	24.98	9.71	84.96	6.52
40.0	13.75	30.0	7.47	60.2	11.6	49.03	11.96	26.04	10.27	90.16	4.49
46.4	14.10	30.1	7.60	69.2	11.6	49.97	12.29	27.61	10.37	94.91	2.55
50.0	14.10	33.3	10.79	83.8	8.0	49.97	11.99	29.01	10.82	100.00	0.475
55.0	13.85	35.1	11.88	100.0	2.27	51.07	12.09	29.94	11.35		
59.6	13.65	38.1	10.35			52.61	11.72	31.97	11.56	DATA SET 8 (T = 273.2 K)	
60.0	13.58	39.8	9.24	DATA SET 5 (T = 293.2 K)		54.06	11.66	33.05	11.16		
64.0	12.90	40.0	8.94			55.11	11.97	33.90	11.56		
64.8	12.90	42.2	7.75			57.09	12.14	35.05	11.56	10.00	6.27
66.7	12.50	45.0	6.40	14.8	8.65	59.00	11.28	36.03	12.17	15.01	8.21
69.2	12.00	46.4	5.94	24.4	11.22	60.15	11.02	37.14	12.10	17.51	9.28
74.3	10.90	48.1	5.26	45.3	2.175	61.66	10.97	38.07	11.74	18.93	9.65*
83.8	8.13	49.2	4.24	56.3	13.59	63.21	10.60	39.02	12.45	20.01	10.33
96.9	3.62	50.0	3.63			64.09	10.63	39.99	11.84	21.07	10.32
		50.5	3.98	DATA SET 6 (T = 20.8 K)		65.16	10.42	41.10	11.82	21.55	10.81
DATA SET 2 (T = 293.2 K)		53.5	6.04			67.19	10.18	42.58	11.84	22.93	10.86
		55.0	6.60			69.10	9.73	44.11	12.54	24.08	11.16
		59.6	9.05	10.00	4.54	71.07	9.30	46.07	12.34	24.98	11.49
38.1	13.70	60.0	9.10	15.01	6.43	72.70	9.19	47.59	12.49	24.98	11.22
39.8	13.45	64.0	11.30	17.51	7.46	74.16	8.84	49.03	12.39	26.04	11.85
40.0	13.50	64.8	12.21	18.93	7.85	75.22	8.67	49.97	12.75*	27.61	11.92
42.2	11.30	66.7	12.91	20.01	8.44	76.09	8.23	49.97	12.44	29.01	12.36
45.0	9.30	69.2	12.50	21.07	8.49	77.19	8.03	51.07	12.52	29.94	12.97
46.4	8.20	74.3	11.63	21.55	9.03	78.76	7.23	52.61	12.18	31.97	13.18
48.1	7.35	83.8	8.25	22.93	8.99	80.14	6.96	54.06	12.12	33.05	12.72
49.2	6.70	96.9	3.62	24.08	9.29	81.31	6.95	55.11	12.44	33.90	13.19
50.0	5.75	100.0	2.22	24.98	9.62	82.74	6.67	57.09	12.67	35.05	13.18
50.5	5.80			24.98	9.33	84.96	6.01	59.00	11.75	36.03	13.86
53.5	7.50	DATA SET 4 (T = 273.2 K)		26.04	9.87	90.16	4.01	60.15	11.53	37.14	13.73
55.0	8.10			27.61	9.98	94.91	2.06	61.66	11.47	38.07	13.30
59.6	12.00			29.01	10.42	100.00	0.0333	63.21	11.12	39.02	14.08
60.0	11.30	0.0	1.9	29.94	10.93*			64.09	11.14	39.99	13.40
64.0	12.90	1.8	3.2	31.97	11.14*			65.16	10.92	41.10	13.37
		4.4	4.7	33.05	10.75			67.19	10.69	42.58	13.39
		10.9	7.3	33.90	11.10			69.10	10.84	44.11	14.13

* Not shown in figure.

TABLE 21. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER-GOLD ALLOY SYSTEM (Composition Dependence) (continued)

DATA SET 8 (cont.) (T = 273.2 K)

C	ρ
46.07	13.93
47.59	14.08
49.03	13.95
49.97	14.37
49.97	14.03
51.07	14.11
52.62	13.78
54.06	13.74
55.11	14.10
57.09	14.49
59.00	13.37
60.15	13.23
61.66	13.09
63.21	12.80
64.09	12.85
65.16	12.61
67.19	12.40
69.10	11.97
71.07	11.85
72.70	11.47
74.16	11.14
75.22	10.99
76.09	10.52
77.19	10.22
78.76	9.47
80.14	9.18
81.31	9.15
82.74	8.90
84.96	8.24
90.16	6.16
94.91	4.20
100.00	2.07

DATA SET 9 (T = 20.8 K)

C	ρ
10.00	4.51
15.01	6.48
17.51	7.54
18.93	7.75
20.01	7.22
21.07	4.66
21.55	6.80
22.93	3.09
24.08	1.66
24.98	1.85
24.98	1.37
26.04	1.63

DATA SET 9 (cont.) (T = 20.8 K)

C	ρ
27.61	2.63
29.01	3.89
29.94	5.29
31.97	7.89
33.05	8.48
33.90	9.75
35.05	10.19
36.03	11.12
37.14	11.42
38.07	9.24
39.02	8.41
39.99	8.11
41.10	7.17
42.58	5.97
44.11	4.17
46.07	3.89
47.59	1.43
49.03	1.48
49.97	1.65
49.97	0.93
51.07	1.28
52.61	1.96
54.06	2.73
55.11	3.96
57.09	4.78
59.00	6.15
60.15	6.86
61.66	7.16
63.21	10.52
64.09	10.50
65.16	10.45
67.19	10.25
69.10	9.85
71.07	9.43
72.70	9.29
74.16	8.94
75.22	8.73
76.09	8.26
77.19	8.08
78.76	7.25
80.14	6.84
81.31	6.94
82.74	6.01
84.96	5.98
90.16	3.99
94.91	2.05
100.00	0.0372

DATA SET 10* (T = 78.2 K)

C	ρ
10.00	4.81
15.01	6.82
17.51	7.89
18.93	8.16
20.01	7.78
21.07	5.21
21.55	7.30
22.93	3.68
24.08	2.27
24.98	2.46
24.98	1.97
26.04	2.25
27.61	3.23
29.01	4.48
29.94	5.89
31.97	8.48
33.05	9.05
33.90	10.30
35.05	10.72
36.03	11.63
37.14	11.93
38.07	9.74
39.02	8.94
39.99	8.61
41.10	7.67
42.58	6.50
44.11	4.75
46.07	4.41
47.59	2.05
49.03	2.09
49.97	2.28
49.97	1.56
51.07	1.89
52.61	2.58
54.06	3.33
55.11	4.57
57.09	5.34
59.00	6.70
60.15	7.41
61.66	7.70
63.21	11.08
64.09	11.06
65.16	10.99
67.19	10.78
69.10	10.37
71.07	9.94
72.70	9.79
74.16	9.45

DATA SET 10 (cont.)* (T = 78.2 K)

C	ρ
75.22	9.24
76.09	8.78
77.19	8.58
78.76	7.75
80.14	7.33
81.31	7.44
82.74	7.08
84.96	6.48
90.16	4.48
94.91	2.54
100.00	0.477

DATA SET 11* (T = 273.2 K)

C	ρ
10.00	6.22
15.01	8.27
17.51	9.39
18.93	9.78
20.01	9.77
21.07	7.53
21.55	9.23
22.93	6.00
24.08	4.64
24.98	4.86
24.98	4.34
26.04	4.71
27.61	5.58
29.01	6.78
29.94	8.21
31.97	10.66
33.05	11.07
33.90	12.27
35.05	12.58
36.03	13.48
37.14	13.80
38.07	11.61
39.02	10.95
39.99	10.53
41.10	9.60
42.58	8.55
44.11	6.91
46.07	6.42
47.59	4.25
49.03	4.28
49.97	4.56
49.97	3.63
51.07	4.12

DATA SET 11 (cont.)* (T = 273.2 K)

C	ρ
52.61	4.79
54.06	5.49
55.11	6.82
57.09	7.36
59.00	8.69
60.15	9.38
61.66	9.65
63.21	12.91
64.09	12.90
65.16	12.76
67.19	12.53
69.10	12.10
71.07	11.66
72.70	11.50
74.16	11.15
75.22	10.95
76.09	10.46
77.19	10.28
78.76	9.45
80.14	9.01
81.31	9.13
82.74	8.76
84.96	8.20
90.16	6.14
94.91	4.17
100.00	2.08

DATA SET 12 (T = 273.2 K)

C	ρ
0.0	2.00
0.9	5.81
1.7	7.41
2.2	9.80
2.9	13.00
3.9	16.90
4.6	18.20
5.5	14.70
6.7	9.09
8.2	6.13
9.6	4.90
11.2	7.25
13.1	9.80
15.9	14.90
19.4	9.43
22.0	7.14
24.4	5.75
27.1	8.93

DATA SET 12 (cont.) (T = 273.2 K)

C	ρ
29.3	11.60
31.0	13.30
34.0	13.20

DATA SET 13 (T = 273.2 K)

C	ρ
0.0	2.00
0.9	5.81
1.7	7.41
2.2	9.80
2.9	13.0
3.9	16.9
4.7	16.9
7.2	14.3
10.8	14.3
12.4	15.9
15.1	15.9
16.1	14.9
30.3	14.9
34.0	13.2
37.9	11.4
40.9	9.52
45.2	7.81
51.1	6.21
55.9	5.21
62.2	4.57
67.6	4.03
72.9	3.52
79.2	3.00
83.5	2.63
88.3	2.33
94.5	1.93
100.0	1.55

DATA SET 14 (T = 298.2 K)

C	ρ
1	2.15
1	2.28
2	2.70
5	4.10
10	6.60
15	8.68
20	10.05
22.5	11.06
24	10.55
25	10.90

* Not shown in figure.

TABLE 21. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER-GOLD ALLOY SYSTEM (Composition Dependence) (continued)

DATA SET 14 (cont.) (T = 296.2 K)

C	ρ
25	11.33*
26	11.25
27.5	12.02
30	12.47
35	13.36
40	14.02
45	14.22
47.5	14.06*
50	14.15
52.5	14.02
55	14.04
60	13.49
75	11.05

DATA SET 15 (T = 4.2 K)

C	ρ
1	0.44
2	0.90
5	2.37
10	4.66
15	6.72
20	8.10
22.5	8.95
24	8.66
25	9.09
25	9.30*
26	9.29
27.5	9.94
30	10.35
35	11.24
40	11.83
45	12.02
47.5	11.93
50.	11.89
52.5	11.68
55	11.68
60	11.06
75	8.66

DATA SET 16 (T = 4.2 K)

C	ρ
10	4.92
15	6.94
20	6.67
22.5	3.04

DATA SET 16 (cont.) (T = 4.2 K)

C	ρ
24	1.62
25	0.97
26	1.46
27.5	2.80
30	5.94
35	9.30
40	7.71
45	3.79
47.5	2.06
50	0.91
52.5	2.25
55	4.30
60	7.27
75	8.38

DATA SET 17* (T = 4.2 K)

C	ρ
0.076	0.0404
0.27	0.142
0.48	0.252
1.00	0.526
1.84	0.971

DATA SET 18 (T = 1273 K)

C	ρ
25	29.9
28	30.3
30	31.8
32	31.9
34	31.9
40	33.3
50	34.2
60	34.3
66.7	33.6
69	33.9
70	34.1
72	34.4
75	33.8
77	33.5
87.5	32.0

DATA SET 19 (T = 1373 K)

C	ρ
0	21.1
12.5	26.3
25	30.8
28	31.3
30	32.6
32	32.9
34	32.9
40	34.3
50	35.4
60	35.4
66.7	34.9
69	35.4
70	35.3
72	35.6
75	35.2
77	34.9
87.5	33.5
100	31.7

DATA SET 20 (T = 1473 K)

C	ρ
0	22.0
12.5	27.4
25	31.7
28	32.1
30	33.5
32	34.0
34	33.8
40	35.2
50	36.5
60	36.4
66.7	36.0
69	36.7
70	36.5
72	36.8
75	36.5
77	36.2
87.5	35.0
100	33.0

DATA SET 21 (T = 273.2 K)

C	ρ
0	3.12
10.4	9.35
20.7	17.5

DATA SET 21 (cont.) (T = 273.2 K)

C	ρ
31.9	20.0
57.6	18.8
69.8	15.9
80.0	11.8
90.5	6.99
100	2.27

DATA SET 22 (T = 373.2 K)

C	ρ
0	4.39
10.4	11.0
20.7	18.2
31.9	21.7
57.6	20.0
69.8	16.9
80.0	12.2
90.5	7.46
100	3.12

* Not shown in figure.

3.4. Copper-Nickel Alloy System

Sixty-five data-source references are available in the literature on the electrical resistivity of the Cu-Ni alloy system. From these references, a total of 244 data sets, 18 of which are merely single data points, have been extracted along with sample characterization and measurement information. One hundred and fifty-five of the data sets are for the electrical resistivity of Cu + Ni alloys as a function of temperature covering the temperature range from 1 to 1273 K, which are listed in table 23, tabulated in table 24, and shown in figure 19; 71 of the data sets are for the electrical resistivity of Ni + Cu alloys as a function of temperature covering the range from 1.8 to 1273 K, which are listed in table 25, tabulated in table 26, and shown in figure 20; and 18 of the data sets are isotherms of the electrical resistivity as a function of composition, which are listed in table 27, tabulated in table 28, and shown in figure 22. In order to show both functional dependencies of the electrical resistivity, a few of the data sets have been presented in the tables and figures both for temperature dependence and for composition dependence.

Considerable evidence now exists to support the assertion that the Cu-Ni alloy system does not form a continuous series of solid solutions with truly random atomic arrangements. Rather it appears that, for certain alloy compositions and thermal treatments, Ni atoms tend to segregate from the random mixture to form short-range clusters. Some of the earliest evidence for this effect came from electrical resistivity and Hall constant measurements by Köster and Schüle [142] who concluded that short-range ordering occurs in alloys with from 15 to 45 wt.% Ni at temperatures below 923 K, with a maximum degree of order at about 723 K. The effect of the short-range ordering was to decrease the electrical resistivity. In a similar series of experiments, Schüle and Kehrer [14] (Cu + Ni data sets 56-63 and Ni + Cu data sets 40-41) concluded that clustering begins to form below 873 K and increases down to 623 K under conditions of slow cooling. In specimens quenched from homogenization temperatures of greater than 1273 K at a rate of at least 10,000 K s^{-1}, Schüle and Kehrer found a greater degree of clustering at lower temperatures, which they attributed to the presence of excess vacancies frozen-in by the quench from high temperatures. Hedman and Mattuck [144] (Cu + Ni data sets 16-18) quenched alloys with 41 to 47 wt.% Ni from 1273 K and found that subsequent annealing at

temperatures from about 473 to 723 K resulted in a decrease in the room temperature resistivity, with a minimum resistivity for annealing temperatures between 553 K and 608 K. They explained these results by suggesting that quenched-in vacancies, by their migration, allow the formation of clusters which produce the observed decrease in resistivity. Robbins et al. [145] came to a very similar interpretation from an analysis of magnetic susceptibility and cluster specific heat data. Mozer et al. [146] found direct evidence for the existence of Ni clusters in a diffuse neutron scattering experiment on a 47.5 at.% Ni specimen prepared with Ni^{62} to enhance the difference in scattering powers of Cu and Ni. The specimen, which was furnace-cooled from a temperature of 1294 K, showed a type of clustering in which "the probability of finding a Ni atom in the first-neighbor shell around a Ni atom increases from the random probability of 0.475 to 0.539. The clustering was found to be most pronounced for the first-neighbor shell, and in fact the solid solution is essentially random beyond this shell." By a consideration of diffusion rates in alloys near the composition of their specimen, Mozer et al. concluded that no cooling rate would successfully quench-in the local atomic arrangements characteristic of the alloy at 1273 K because the diffusion rates are too great at this elevated temperature. On the other hand, according to the authors, at around 773 to 873 K the diffusion rates become slow enough that any reasonable cooling rate, even furnace cooling, will freeze-in the atomic structure and prevent changes below 773 K. Hicks et al. [147] have confirmed this short-range clustering effect in neutron experiments of their own on specimens with compositions near the ferromagnetic critical composition.

The magnetic critical composition for Cu-Ni alloys and the Curie temperature for specific compositions are dependent on the degree of clustering present. Hedman and Mattuck [144] and Kussmann and Wollenberger [148] prepared specimens with different degrees of clustering by using appropriate heat and mechanical treatments. Their results are shown in figure 21. In both cases, specimens annealed in the 553 to 673 K range, where clustering is greatest, showed higher Curie temperatures than alloys quenched from 1073 or 1273 K. Cold-work, which presumably reduces the degree of clustering, produced specimens whose Curie temperatures were much lower than those of specimens quenched from higher temperatures. The effect of clustering on the Curie temperature is evident in alloys with as much as 70 at.% Ni and as little as 43 at.% Ni.

In addition to the data mentioned above, figure 21 shows a rather eclectic collection of measurements of Curie temperatures produced by a wide diversity of methods for alloy compositions from the critical composition to pure Ni. Mott [44] predicted a linear dependence of the Curie temperature on atomic composition and predicted a critical composition of 40 at.% Ni. As shown in the figure, this linear dependence is supported by the data for compositions with more than about 75 at.% Ni, but for lower concentrations of Ni, a discrepancy arises. In this region, the data of Hedman and Mattuck [144] and Kussmann and Wollenberger [148] for specimens quenched from high temperature fall very near a straight line which is determined by a critical composition of 40 at.% Ni (at which the Curie temperature is zero) and a Curie temperature for pure Ni of 631 K (represented by the dashed line in figure 21). However, measurements by Hicks et al. [147], Rode et al. [150], Ahmad and Greig [151], and Ahern et al. [152] show Curie temperatures which are not only considerably lower, but also show a non-linear dependence on composition near the critical composition. Two considerations might contribute to an explanation of this discrepancy, which is particularly evident for the composition range studied by Hedman and Mattuck. First, the degree of clustering may be lower for the non-linear group of measurements, resulting in lowered Curie temperatures. Indeed, the Curie temperatures determined by Hedman and Mattuck and by Kussman and Wollenberger for deformed specimens with a low degree of clustering show remarkable agreement with the Curie temperatures determined by Hicks et al., Rode et al., and Ahmad and Greig. However, with the information available, it is difficult to determine what specific differences in thermal and mechanical histories of the specimens gave rise to this difference in degree of clustering. For example, both Hicks et al. and Hedman and Mattuck quenched specimens from 1273 K after homogenization, yet apparently produced specimens of greatly differing degrees of clustering. Second, the experimental arrangement used by Hedman and Mattuck did not allow measurements of the magnetic susceptibility at sufficiently low temperatures, and in some cases required extrapolation of the inverse susceptibility from temperatures as much as 165 K above the Curie temperature.

In this work the lower set of non-linear Curie temperatures, which are believed to be representative of the Curie temperatures of alloy specimens with a low degree of clustering, has been selected. The selected Curie temperatures are shown in figure 21 by a solid line and follow the data of Hicks et al.,

Rode et al., and Ahmad and Grieg closely. The data of Ahern et al. are greater in magnitude than the selected values, though they follow the trend of the selected values as a function of composition. Above about 77 at.% Ni, the solid line and the dashed line, representing the linear relationship suggested by Mott, are congruent.

A number of features of the temperature dependence of the electrical resistivity have received considerable interest in the research literature and are worth noting. First, at low temperatures (up to about 80 K), alloys with from about 30 to 45 wt.% Ni show shallow minima in the electrical resistivity, as shown in figure 19. This feature has been noted and discussed by Skoskiewicz and Baranowski [170], Crangle and Butcher [171], Houghton et al. [172,173], Kondorskii et al. [174], Ahmad and Greig [175], Eagen [176], Eagen and Legvold [177], and Legvold et al. [178], amongst others. Second, alloys with from about 35 to 55 wt.% Ni also show a high temperature (near 700 K) minimum in the electrical resistivity, which has been noted and discussed by Ahmad and Greig [151,175], Houghton et al. [173], and Schüle and Kehrer [143], amongst others. Third, according to Ahmad and Greig [151] and Schüle and Kehrer [143], the electrical resistivity of specimens with from about 30 to 60 wt.% Ni measured during heating is appreciably greater than the electrical resistivity measured during cooling, for temperatures below about 700 to 770 K. Above 700 to 770 K, the heating and cooling curves are the same. Ahmad and Greig found differences of about 1% and Schüle and Kehrer found differences of as much as $3.5 \times 10^{-8}\ \Omega\,m$. Ahmad and Greig suggested differences in the degree of clustering as an explanation of this phenomenon.

One feature of the composition-dependent resistivity worthy of note is the shape of the $\rho_{4.2\,K}$ isotherm shown in figure 22. It does not have the rounded, parabolic shape characteristic of the Cu-Au alloy system, but instead is similar to the Matterhorn silhouette of the Cu-Pd alloy system. As the maximum (about 48 at.% Ni) of the residual electrical resistivity is approached from the Ni-rich side, a rapid increase in slope is observed at around 60 to 65 at.% Ni. Another feature is the slight change of slope in the isotherms at the transition from ferromagnetic to paramagnetic behavior. This can be seen, for example, at around 70 at.% Ni in the 293 K isotherm of figure 22. Finally, it should be noted that, as the temperature increases, the maxima in the isotherms of the electrical resistivity as a function of composition are shifted to increasingly greater Ni concentrations.

The recommended values for the electrical resistivity of Cu-Ni alloys were generated by a careful examination and critical analysis of the entire body of experimental data shown in figures 19, 20, and 22. In order to assist in the generation of recommended values for the selected compositions, selected more reliable data were plotted as isotherms of the electrical resistivity as a function of composition at 4.2, 30, 80, 150, 230, 300, 400, 500, 600, 700, 900, and 1100 K. The data were graphically interpolated and smoothed as a function of composition and temperature successively in order to produce the final recommendations, which are shown in figures 16, 17, and 18 as a function of temperature, in figure 22 as a function of composition at selected temperatures, and in table 22. The additional figure 18 in linear scale is given for showing more clearly the recommended curves at high temperatures.

In the generation of recommended values for the resistivity of the Cu-Ni system, we have relied heavily upon the data of Ahmad and Greig [151,175] (Cu + Ni data sets 145-147, 152, Ni + Cu data sets 56-59, and Cu-Ni data sets 14-15), which constitute one of the most comprehensive sets of data in their coverage of a wide range of both temperature and composition. From 30 to 50 wt.% Ni at low temperatures, the data of Houghton et al. [172] (Cu + Ni data sets 38-44) are about 1.0 to 1.5 x $10^{-8}\,\Omega$m higher than the data of Ahmad and Greig, while the data of Crangle and Butcher [171] (Cu + Ni data sets 51-55) are about the same amount lower. The data of Legvold et al. [178] (Cu + Ni data sets 103-108) are in good agreement. In this range, the recommended values are consistent with all these data. However, near 50 wt.% Ni at low temperatures, only the specimens of Ahmad and Greig [151] (Ni + Cu data sets 58-59) and Crangle and Butcher [171] (Ni + Cu data set 39) are available, yet their resistivities differ by as much as 6 x $10^{-8}\,\Omega$m. (Near room temperature the resistivities for these specimens are in good agreement.) In this region of composition, the data of Ahmad and Greig have been given preference and a large uncertainty is assigned to the recommended values. Again at high temperatures, there is a conflict between the data of Ahmad and Greig [151] (Ni + Cu data sets 56-59) for alloys with greater than 50 wt.% Ni and the data of Yao [158] (Ni + Cu data sets 60-63) and Svensson [164] (Ni + Cu data sets 19-22). Both Yao and Svensson report resistivities which are as much as 3 to 4 x $10^{-8}\,\Omega$m higher than the data of Ahmad and Greig. The data of Yao are believed to show too great an increase with temperature above the Curie

temperature, as can be seen even with his pure Ni specimen. The data of Svensson were disregarded because they were often too high over the whole composition range and because the specimens were not well characterized.

The resulting recommended electrical resistivity values for Cu, Ni, and for 25 Cu-Ni binary alloys are presented in table 22 and shown in figures 16, 17, 18, and 22. The recommended values for Cu and for Ni are for well-annealed high-purity specimens, but those values for temperatures below about 100 K are applicable only to Cu and Ni having residual electrical resistivities as given at 1 K in table 22. The alloys for which the recommended values are generated are well-homogenized alloys with a low degree of clustering and have not been quenched or cold-worked severely. The recommended values cover a full range of temperature from 1 K to 1100 K. These values are not corrected for the thermal expansion of the material. The estimated uncertainties in the values for the various alloys and for different temperature ranges are explicitly stated in a footnote to table 22. A few of the low-temperature values for Cu + 50 % Ni alloy and the two values for molten Ni are indicated as provisional because their uncertainties are greater than ±5%.

TABLE 22. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-NICKEL ALLOY SYSTEM†

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega\ m$]

Cu: 100.00% (100.00 At.%) Ni: 0.00% (0.00 At.%)		Cu: 99.50% (99.46 At.%) Ni: 0.50% (0.54 At.%)		Cu: 99.00% (98.92 At.%) Ni: 1.00% (1.08 At.%)		Cu: 97.00% (96.26 At.%) Ni: 3.00% (3.24 At.%)		Cu: 95.00% (94.61 At.%) Ni: 5.00% (5.39 At.%)		Cu: 90.00% (89.27 At.%) Ni: 10.00% (10.73 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	0.00200	1	0.58*	1	1.16*	1	3.53*	1	5.89	1	11.79
4	0.00200	4	0.58	4	1.16	4	3.53	4	5.89	4	11.79
7	0.00200	7	0.58*	7	1.16*	7	3.53*	7	5.89	7	11.79
10	0.00202	10	0.58*	10	1.16*	10	3.53*	10	5.89	10	11.79
15	0.00218	15	0.58*	15	1.16*	15	3.53*	15	5.89	15	11.79
20	0.00280	20	0.59*	20	1.17	20	3.53	20	5.89	20	11.79
25	0.00450	25	0.59*	25	1.17	25	3.53	25	5.90	25	11.79
30	0.00830	30	0.59*	30	1.17	30	3.54	30	5.90	30	11.80
40	0.0240	40	0.61*	40	1.19	40	3.56	40	5.93	40	11.80
50	0.0520	50	0.63*	50	1.21	50	3.59	50	5.97	50	11.82
60	0.0974	60	0.67*	60	1.25	60	3.62	60	6.00	60	11.88
70	0.154	70	0.71	70	1.28	70	3.67	70	6.02	70	11.91
80	0.216	80	0.77	80	1.33	80	3.71	80	6.09	80	11.97
90	0.282	90	0.82*	90	1.39	90	3.76	90	6.13	90	12.01
100	0.349	100	0.88*	100	1.45	100	3.82	100	6.19	100	12.08
150	0.701	150	1.21*	150	1.81	150	4.15	150	6.52	150	12.46
200	1.048	200	1.59	200	2.20	200	4.55	200	6.94	200	12.93
250	1.388	250	1.95	250	2.56	250	4.97	250	7.38	250	13.44
273	1.544	273	2.10	273	2.71	273	5.17	273	7.60	273	13.69
293	1.678	293	2.23	293	2.85	293	5.32	293	7.77	293	13.89
300	1.725	300	2.30	300	2.91	300	5.39	300	7.82	300	13.96
350	2.061	350	2.66	350	3.27	350	5.77	350	8.22	350	14.40
400	2.398	400	3.00	400	3.62	400	6.18	400	8.62	400	14.81
500	3.079	500	3.69	500	4.34	500	6.96	500	9.47	500	15.58
600	3.771	600	4.37	600	5.03	600	7.65	600	10.18	600	16.28
700	4.481	700	5.09	700	5.78	700	8.37	700	10.90	700	16.96
800	5.213	800	5.87	800	6.54	800	9.13	800	11.69	800	17.62
900	5.973	900	6.61	900	7.31	900	9.98	900	12.54	900	18.36
1000	6.766	1000	7.39*	1000	8.10*	1000	10.78*	1000	13.41*	1000	19.10*
1100	7.596	1100	8.25*	1100	8.99*	1100	11.69*	1100	14.31*	1100	19.99*
1200	8.470										
1300	9.395										
1357.6	9.946(s)										
1358	21.01(ℓ)										
1700	24.41										

† Uncertainties in the electrical resistivity values are as follows:

100.00 Cu - 0.00 Ni: ±3% up to 100 K, ±1% above 100 K to 250 K, ±0.5% above 250 K to 350 K, ±1% above 350 K to 500 K, ±4% above 500 K to 1357.6 K, and ±5% above 1357.6 K.
99.50 Cu - 0.50 Ni: ±5%.
99.00 Cu - 1.00 Ni: ±5%.
97.00 Cu - 3.00 Ni: ±5%.
95.00 Cu - 5.00 Ni: ±5% below 400 K and ±4% from 400 to 1100 K.
90.00 Cu - 10.00 Ni: ±5% below 400 K and ±3% from 400 to 1100 K.

* In temperature range where no experimental data are available.

TABLE 22. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-NICKEL ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Cu: 85.00% (83.96 At.%) Ni: 15.00% (16.04 At.%)		Cu: 80.00% (78.71 At.%) Ni: 20.00% (21.29 At.%)		Cu: 75.00% (73.49 At.%) Ni: 25.00% (26.51 At.%)		Cu: 70.00% (68.31 At.%) Ni: 30.00% (31.69 At.%)		Cu: 65.00% (63.18 At.%) Ni: 35.00% (36.82 At.%)		Cu: 60.00% (58.09 At.%) Ni: 40.00% (41.91 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	17.69*	1	23.61	1	29.55*	1	35.48*	1	41.43*	1	46.19*
4	17.69	4	23.61	4	29.55	4	35.47	4	41.39	4	46.17
7	17.69*	7	23.61	7	29.55*	7	35.45*	7	41.35	7	46.13*
10	17.69*	10	23.61	10	29.55*	10	35.42*	10	41.32	10	46.11*
15	17.69*	15	23.61	15	29.55*	15	35.41*	15	41.29	15	46.09*
20	17.69	20	23.61	20	29.55	20	35.40	20	41.27	20	46.04
25	17.69	25	23.61	25	29.55	25	35.40	25	41.25	25	46.02
30	17.69	30	23.61	30	29.55	30	35.41	30	41.24	30	45.99
40	17.71	40	23.63	40	29.58	40	35.42	40	41.23	40	45.93
50	17.75	50	23.68	50	29.60	50	35.48	50	41.27	50	45.90
60	17.79	60	23.71	60	29.62	60	35.52	60	41.30	60	45.86
70	17.83	70	23.73	70	29.68	70	35.58	70	41.32	70	45.82
80	17.90	80	23.79	80	29.71	80	35.63	80	41.37	80	45.80
90	17.97	90	23.82	90	29.78	90	35.69	90	41.39	90	45.78
100	18.01	100	23.89	100	29.82	100	35.73	100	41.40	100	45.76
150	18.39	150	24.22*	150	30.16	150	36.05	150	41.48	150	45.70
200	18.87	200	24.69*	200	30.56	200	36.32	200	41.50	200	45.62
250	19.39	250	25.21*	250	30.99	250	36.58	250	41.50	250	45.51
273	19.63	273	25.46	273	31.19	273	36.67	273	41.50	273	45.43
293	19.83	293	25.66	293	31.35	293	36.72	293	41.49	293	45.38
300	19.90	300	25.72	300	31.40	300	36.76	300	41.48	300	45.35
350	20.32	350	26.12*	350	31.72	350	36.85	350	41.40	350	45.20
400	20.70	400	26.44*	400	31.92	400	36.89	400	41.30	400	45.01
500	21.42	500	26.96*	500	32.18	500	36.82	500	41.10	500	44.70
600	22.04	600	27.41*	600	32.39	600	36.82	600	40.90	600	44.40
700	22.59	700	27.98*	700	32.60	700	36.92	700	40.90	700	44.29
800	23.31	800	28.50*	800	32.88	800	37.10	800	41.09	800	44.52
900	23.95	900	28.98*	900	33.19	900	37.46	900	41.46	900	44.98
1000	24.49*	1000	29.38*	1000	33.60*	1000	37.82	1000	41.86	1000	45.42*
1100	25.06*	1100	29.79*	1100	34.18*	1100	38.34	1100	42.32	1100	45.92*

† Uncertainties in the electrical resistivity values are as follows:

85.00 Cu - 15.00 Ni: ±5% below 400 K and ±3% from 400 to 1100 K.
80.00 Cu - 20.00 Ni: ±5% below 400 K and ±3% from 400 to 1100 K.
75.00 Cu - 25.00 Ni: ±5% below 400 K and ±3% from 400 to 1100 K.
70.00 Cu - 30.00 Ni: ±4%.
65.00 Cu - 35.00 Ni: ±4%.
60.00 Cu - 30.00 Ni: ±4%.

* In temperature range where no experimental data are available.

TABLE 22. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-NICKEL ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Cu: 55.00% (53.04 At.%) Ni: 45.00% (46.96 At.%)		Cu: 50.00% (48.02 At.%) Ni: 50.00% (51.98 At.%)		Cu: 45.00% (43.05 At.%) Ni: 55.00% (56.95 At.%)		Cu: 40.00% (38.12 At.%) Ni: 60.00% (61.88 At.%)		Cu: 35.00% (33.22 At.%) Ni: 65.00% (66.78 At.%)		Cu: 30.00% (28.37 At.%) Ni: 70.00% (71.63 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	49.00*	1	46.60‡*	1	39.34*	1	32.16*	1	27.30*	1	23.40*
4	49.00	4	46.73‡	4	39.41	4	32.19	4	27.37	4	23.43
7	49.00*	7	46.87‡*	7	39.48*	7	32.21*	7	27.43*	7	23.50*
10	49.00*	10	47.01‡*	10	39.57*	10	32.24*	10	27.50*	10	23.56*
15	49.00*	15	47.23‡*	15	39.70*	15	32.32*	15	27.62*	15	23.67*
20	49.00	20	47.49‡	20	39.85	20	32.42	20	27.76*	20	23.78
25	49.00	25	47.73‡	25	40.01	25	32.55	25	27.90*	25	23.89
30	49.00	30	47.98‡	30	40.20	30	32.69	30	28.06*	30	24.01
40	49.00	40	48.40‡	40	40.63	40	33.03	40	28.39*	40	24.28
50	49.00	50	48.82‡	50	41.09	50	33.47	50	28.75*	50	24.56
60	49.00	60	49.21‡	60	41.59	60	33.97	60	29.17*	60	24.89
70	49.00	70	49.52‡	70	42.12	70	34.60	70	29.59	70	25.28
80	49.00	80	49.81‡	80	42.70	80	35.31	80	30.08	80	25.71
90	49.00	90	50.02‡	90	43.30	90	36.02	90	30.62*	90	26.20
100	49.00	100	50.22‡	100	43.92	100	36.77	100	31.27*	100	26.73
150	49.00*	150	50.68	150	47.18	150	40.56	150	35.05*	150	29.98
200	48.89*	200	50.56	200	48.44	200	44.27	200	39.41*	200	33.91
250	48.72*	250	50.31	250	49.07	250	46.92	250	43.28*	250	38.29
273	48.65	273	50.19	273	49.23	273	47.42	273	44.62	273	40.19
293	48.58	293	50.06	293	49.34	293	47.73	293	45.47	293	41.79
300	48.55	300	50.01	300	49.38	300	47.82	300	45.67	300	42.34
350	48.33*	350	49.73	350	49.47	350	48.28	350	46.61*	350	44.51
400	48.09*	400	49.50	400	49.40	400	48.49	400	47.18*	400	45.40
500	47.60	500	49.03	500	49.19	500	48.68	500	47.76*	500	46.39
600	47.17	600	48.74	600	49.02	600	48.81	600	48.15*	600	47.08
700	46.98	700	48.63	700	49.18	700	49.18	700	48.68*	700	47.83
800	47.19	800	48.86	800	49.62	800	49.72	800	49.43*	800	48.82
900	47.62	900	49.39	900	50.29	900	50.53	900	50.39*	900	49.98
1000	48.07	1000	49.92	1000	51.10*	1000	51.49	1000	51.61*	1000	51.27*
1100	48.58	1100	50.49*	1100	52.00*	1100	52.83	1100	53.10*	1100	52.76*

† Uncertainties in the electrical resistivity values are as follows:

55.00 Cu - 45.00 Ni: ±4%.
50.00 Cu - 50.00 Ni: ±10% below 40 K, ±6% from 40 up to 150 K, and ±4% from 150 to 1100 K.
45.00 Cu - 55.00 Ni: ±5%.
40.00 Cu - 60.00 Ni: ±5%.
35.00 Cu - 65.00 Ni: ±5%.
30.00 Cu - 70.00 Ni: ±5%.

‡ Provisional values.

* In temperature range where no experimental data are available.

TABLE 22. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-NICKEL ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

T	Cu: 25.00% (23.55 At.%) Ni: 75.00% (76.45 At.%) ρ	Cu: 20.00% (18.76 At.%) Ni: 80.00% (81.24 At.%) ρ	Cu: 15.00% (14.02 At.%) Ni: 85.00% (85.98 At.%) ρ	Cu: 10.00% (9.31 At.%) Ni: 90.00% (90.69 At.%) ρ	Cu: 5.00% (4.64 At.%) Ni: 95.00% (95.36 At.%) ρ	Cu: 3.00% (2.78 At.%) Ni: 97.00% (97.22 At.%) ρ
1	19.50*	15.60*	11.70*	7.81*	3.90*	2.34*
4	19.53	15.64	11.72	7.82	3.90	2.34
7	19.58*	15.68*	11.76*	7.83*	3.90*	2.34*
10	19.61*	15.72*	11.79*	7.85*	3.91	2.35*
15	19.70*	15.78*	11.82*	7.89*	3.92*	2.37*
20	19.80	15.85	11.89	7.92	3.97	2.38*
25	19.91	15.92	11.95	7.97	4.00	2.40*
30	20.03	16.01	12.01	8.02	4.03	2.42*
40	20.25	16.18	12.13	8.12	4.14	2.50*
50	20.50	16.36	12.30	8.27	4.28	2.61*
60	20.79	16.56	12.49	8.41	4.41	2.73*
70	21.11	16.79	12.69	8.58	4.59	2.89
80	21.48	17.02	12.92	8.76	4.78	3.09
90	21.83	17.35	13.19	9.00	4.98	3.28*
100	22.22	17.66	13.49	9.28	5.20	3.50*
150	24.68*	19.68	15.30	10.90	6.57	4.79*
200	27.82*	22.37	17.62	12.93	8.26	6.41*
250	31.56*	25.64	20.50	15.38	10.37	8.34*
273	33.46	27.38	22.00	16.65	11.49	9.33
293	35.11	28.98	23.35	17.82	12.50	10.26
300	35.69	29.53	23.85	18.26	12.90	10.58
350	39.67*	33.63	27.60	21.51	15.69	13.14*
400	42.81*	37.57	31.38	25.19	18.78	15.98*
500	44.60*	42.12	38.61	32.70	25.77	22.69*
600	45.68*	43.86	41.28	37.78	33.17	30.60*
700	46.60*	45.23	43.21	40.42	36.67	34.99
800	47.77*	46.56	44.72*	42.37	39.11*	37.68
900	49.13*	47.92	46.19*	44.02	41.43*	40.31
1000	50.61*	49.39*	47.88*	46.02*	43.89*	42.94*
1100	52.10*	51.11*	49.90*	48.47*	46.43*	45.57*

† Uncertainties in the electrical resistivity values are as follows:

25.00 Cu - 75.00 Ni: ±5%.
20.00 Cu - 80.00 Ni: ±5%.
15.00 Cu - 85.00 Ni: ±5%.
10.00 Cu - 90.00 Ni: ±5%.
5.00 Cu - 95.00 Ni: ±5%.
3.00 Cu - 97.00 Ni: ±5%.

* In temperature range where no experimental data are available.

TABLE 22. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-NICKEL ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

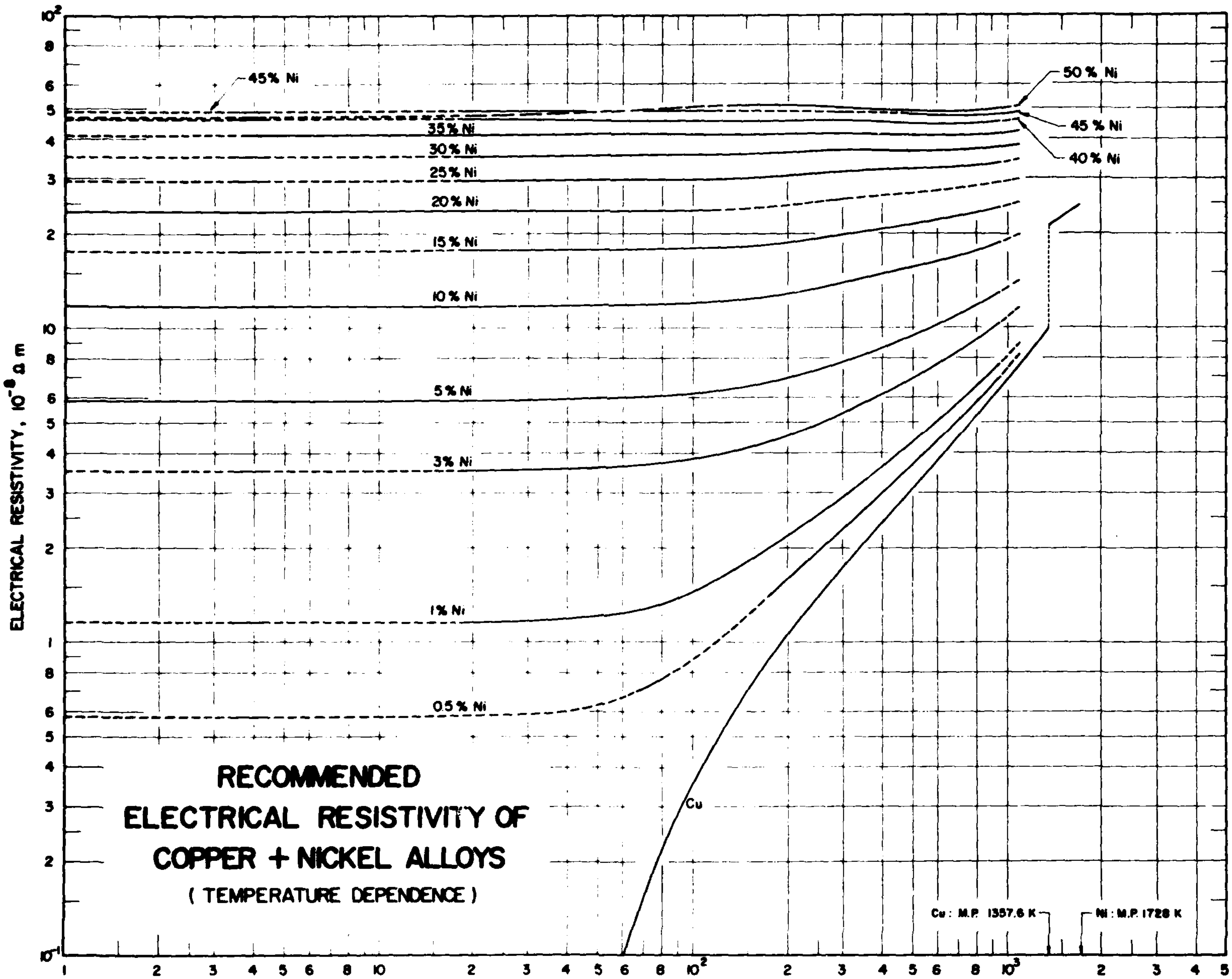
Cu: 1.00% (0.92 At.%) Ni: 99.00% (99.08 At.%)		Cu: 0.50% (0.46 At.%) Ni: 99.50% (99.54 At.%)		Cu: 0.00% (0.00 At.%) Ni: 100.00% (100.00 At.%)	
T	ρ	T	ρ	T	ρ
1	0.78*	1	0.39*	1	0.00320
4	0.78	4	0.39	4	0.00360
7	0.78*	7	0.39*	7	0.00443
10	0.78	10	0.39	10	0.00573
15	0.78*	15	0.39*	15	0.00901
20	0.79	20	0.39	20	0.0140
25	0.80*	25	0.40*	25	0.0212
30	0.82	30	0.41	30	0.0317
40	0.88	40	0.44	40	0.0678
50	0.97*	50	0.52*	50	0.135
60	1.08*	60	0.62*	60	0.242
70	1.21	70	0.76	70	0.377
80	1.37	80	0.93	80	0.545
90	1.57*	90	1.13*	90	0.741
100	1.81*	100	1.36*	100	0.959
150	3.09*	150	2.62*	150	2.21
200	4.57*	200	4.10*	200	3.67
250	6.32*	250	5.82*	250	5.32
273	7.23	273	6.71	273	6.16
293	8.08	293	7.52	293	6.93
300	8.37	300	7.82	300	7.20
350	10.63*	350	10.01*	350	9.34
400	13.18*	400	12.49*	400	11.78
500	19.33*	500	18.48*	500	17.67
600	27.28*	600	26.39*	600	25.54
700	33.11*	700	32.64*	700	32.14
800	36.33*	800	35.94*	800	35.52
900	39.19*	900	38.88*	900	38.58
1000	41.93*	1000	41.60*	1000	41.41
1100	44.61*	1100	44.27*	1200	46.62
				1400	51.73
				1600	56.94
				1728	60.22(s)
				1729	82.24‡(ℓ)
				2000	85.22‡

† Uncertainties in the electrical resistivity values are as follows:

1.00 Cu - 99.00 Ni: ±5% below 400 K and ±3% from 400 to 1100 K.
0.30 Cu - 99.50 Ni: ±5% below 400 K and ±3% from 400 to 1100 K.
0.00 Cu - 100.00 Ni: ±3% below 150 K, ±3% from 150 to 1300 K, ±5% above 1300 K to 1728 K, and ±10% above 1728 K.

‡ Provisional value.

* In temperature range where no experimental data are available.



CINDAS TEMPERATURE , K **FIGURE 16**

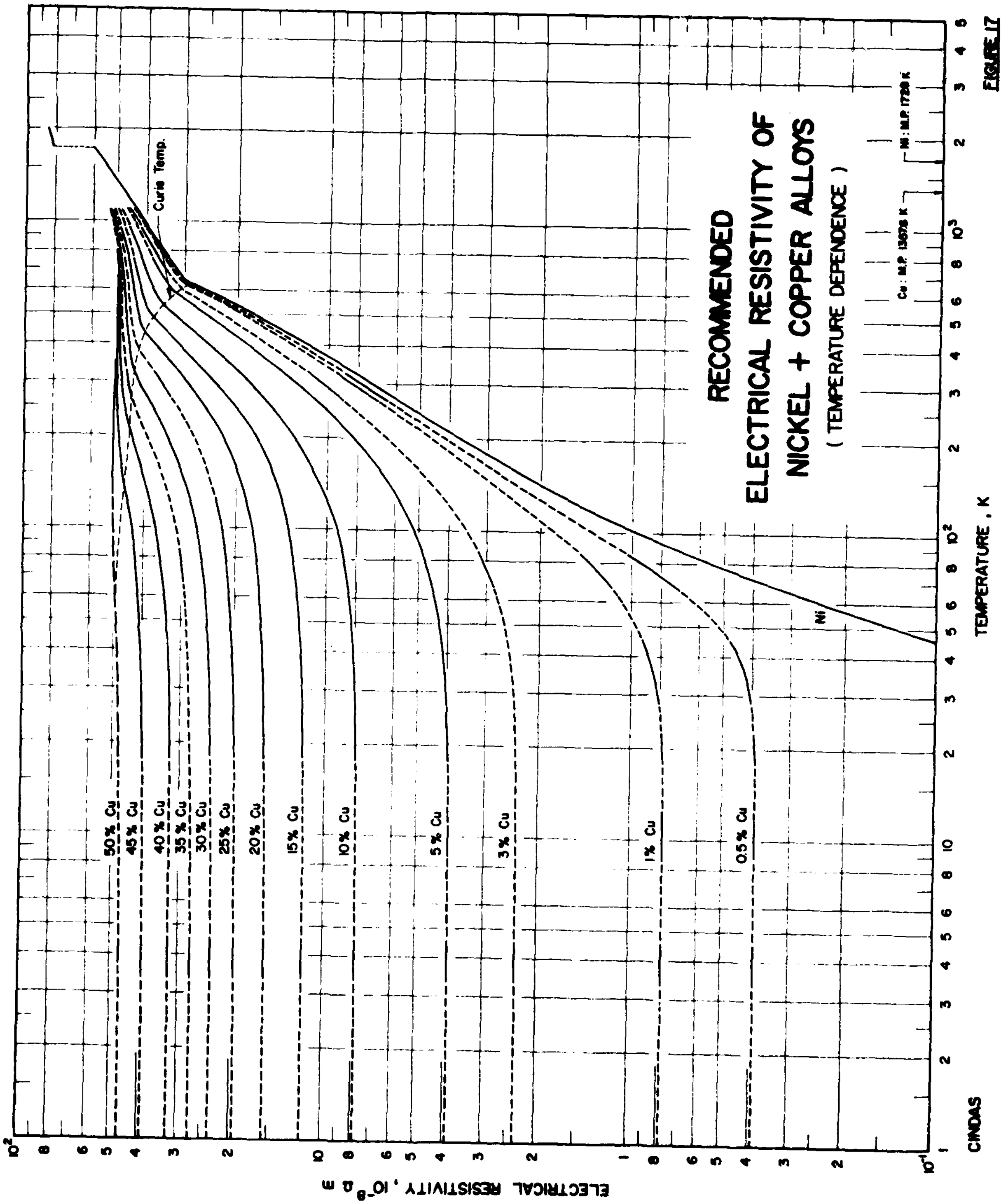
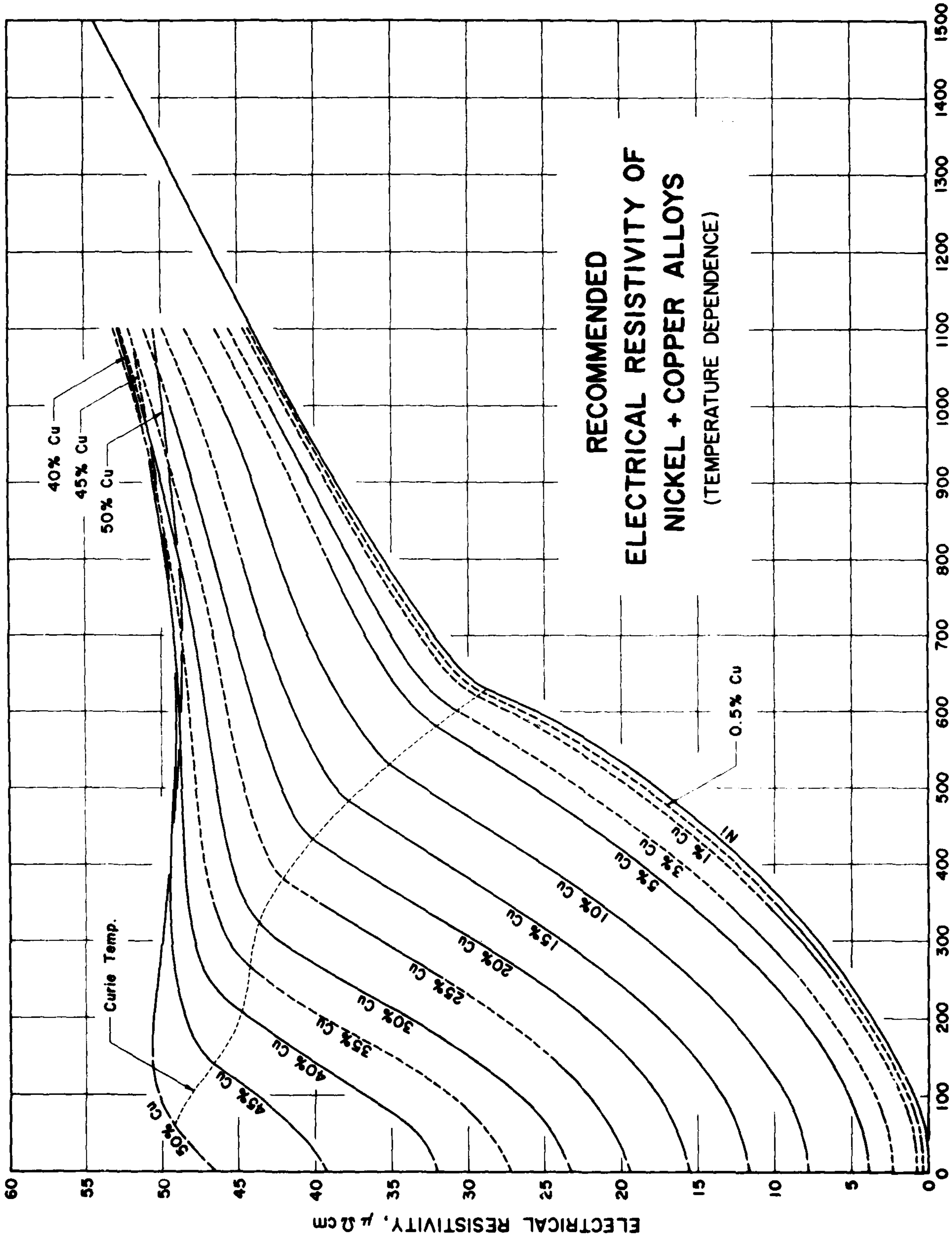

RECOMMENDED
ELECTRICAL RESISTIVITY OF
NICKEL + COPPER ALLOYS
(TEMPERATURE DEPENDENCE)
Curie Temp.
Cu: M.P. 1357.6 K
Ni: M.P. 1728 K
50% Cu
45% Cu
40% Cu
35% Cu
30% Cu
25% Cu
20% Cu
15% Cu
10% Cu
5% Cu
3% Cu
1% Cu
0.5% Cu
Ni
TEMPERATURE, K
ELECTRICAL RESISTIVITY, $10^{-8}\ \Omega$ m
CINDAS

FIGURE 17



CINDAS

FIGURE 18

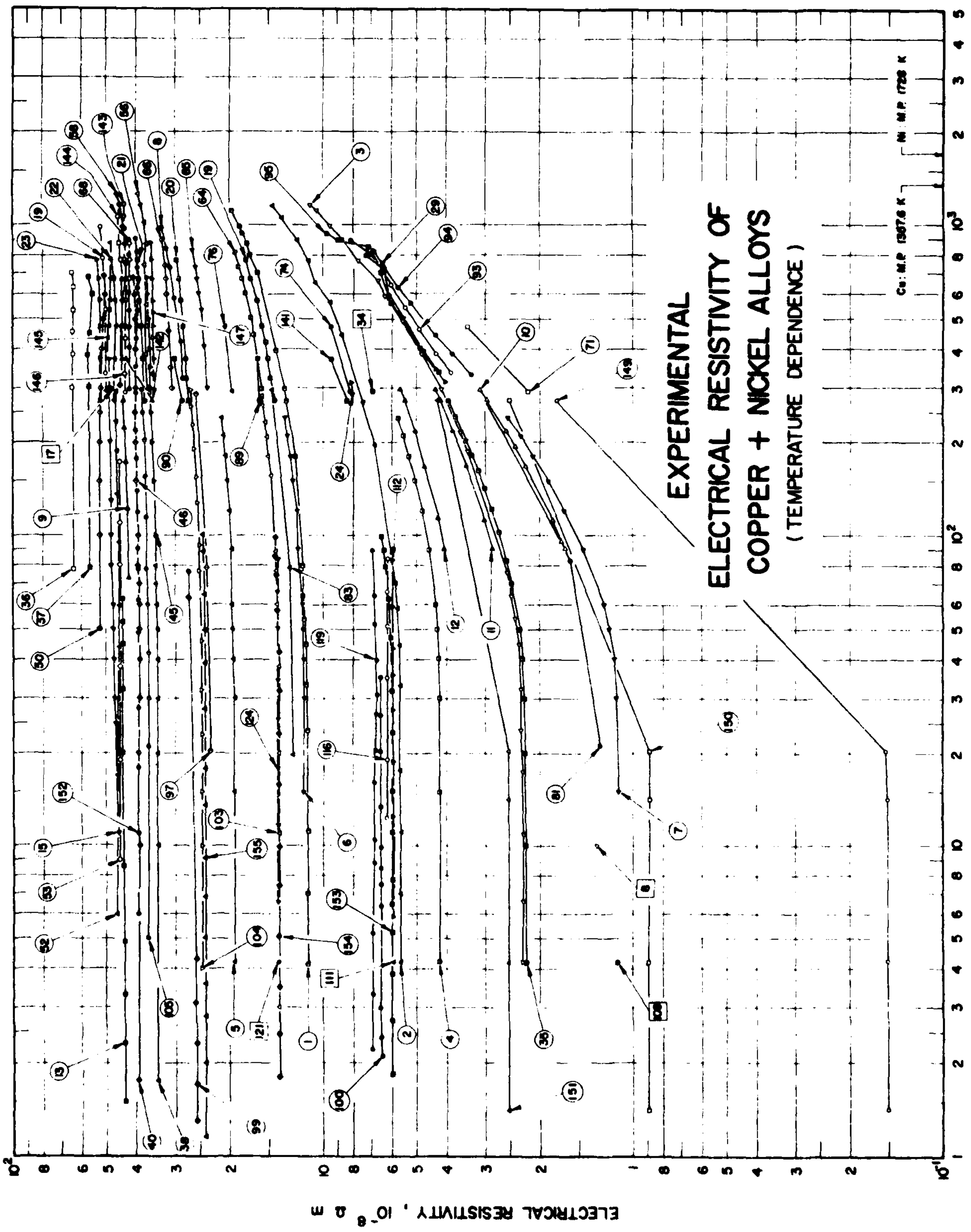

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
COPPER + NICKEL ALLOYS
(TEMPERATURE DEPENDENCE)
TEMPERATURE, K
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
Cu: M.P. 1357.6 K
Ni: M.P. 1726 K
CINDAS

FIGURE 19

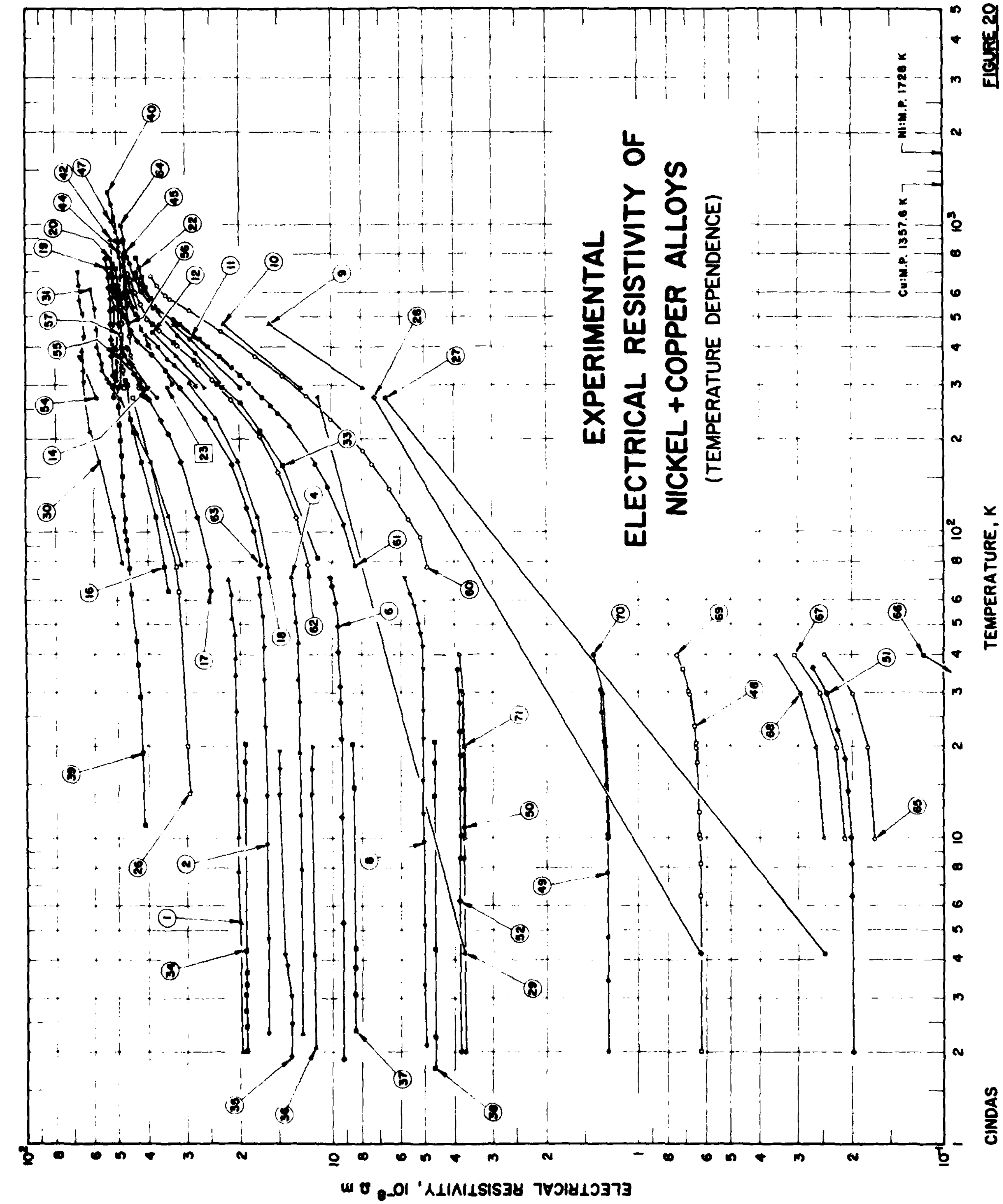

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
NICKEL + COPPER ALLOYS
(TEMPERATURE DEPENDENCE)
Cu: M.P. 1357.6 K
Ni: M.P. 1728 K
TEMPERATURE, K
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
CINDAS

FIGURE 20

TABLE 23. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
1	179	Domenicali, C.A. and Christenson, E. L.	1961	A	4.1-1132			9.33	Calculated composition (10.01 a/o Ni); prepared by melting copper from American Smelting and Refining Co. and nickel from Johnson-Matthey in sealed quartz; annealed at about 500 C for several hours in vacuum.
2	179	Domenicali, C.A. and Christenson, E.L.	1961	A	4.2-1164			4.66	Calculated composition (5.02 a/o Ni); similar to the above specimen.
3	179	Domenicali, C.A. and Christenson, E. L.	1961	A	4.2-1172			1.85	Calculated composition (2.0 a/o Ni); similar to the above specimen.
4	180	Schroeder, P.A., Wolf, R., and Woollam, J.A.	1965	A	4.2-240			3.20	Calculated composition (3.45 a/o Ni); prepared from copper purchased from the American Smelting and Refining Company ($R_{273}/R_{4.2}$ = 1080) and nickel in the form of sponge obtained from Johnson, Matthey, and Company; by melting the components in an alumina crucible by induction heating, and chill casting, ingot drawn down to wire of 0.2 mm diameter, and annealed in vacuum at 680 C.
5	180	Schroeder, P.A., et al.	1965	A	4.2-240			16.01	Calculated composition (17.10 a/o Ni); similar to the above specimen.
6	180	Schroeder, P.A., et al.	1965	A	4.2-240			9.92	Calculated composition (10.65 a/o Ni); similar to the above specimen.
7	180	Schroeder, P.A., et al.	1965	A	4.2-240			0.79	Calculated composition (0.85 a/o Ni); similar to the above specimen.
8	181	Bulow, C. L.	1964		10	E		0.92	Calculated composition (1.0 a/o Ni).
9	182	Javitz, A.E.	1961		73-673	Constanton	60	40	No details reported.
10	126	Linde, J.O.	1932		90-296			1.04	Calculated composition (1.12 a/o Ni).
11	126	Linde, J.O.	1932		90-296			2.00	Calculated composition (2.16 a/o Ni).
12	126	Linde, J.O.	1932		90-296			3.08	Calculated composition (3.32 a/o Ni).
13	174	Kondorskii, E.I., Galkina, O.S., and Chernikova, L.A.	1960	A	1.5-63	1	58	42	No details reported.
14*	174	Kondorskii, E.I., et al.	1960	A	2.0-68	2a	59.25	40.75	No details reported.
15	149	Furukawa, G.T., Reilly, M.L., and Saba, W.G.	1964		11-372	Constanton	57	43	Wire specimen; supplied by Driver-Harris Co.; electrical resistivity values calculated from RT/Ro °C ratios reported by the author (composition comparable to "Advance", probably an error).
16*	144	Hedman, L.E. and Mattuck, R.D.	1962		298.2			46.81	Calculated composition (48.78 a/o Ni); quenching from 1000 C.
17	144	Hedman, L.E. and Mattuck, R.D.	1962		298.2			45.04	Calculated composition (47.00 a/o Ni); similar to the above specimen.
18*	144	Hedman, L.E. and Mattuck, R.D.	1962		298.2			40.87	Calculated composition (42.79 a/o Ni); similar to the above specimen.
19	164	Svensson, B.	1936		273-773			10.78	Calculated composition (11.56 a/o Ni).
20	164	Svensson, B.	1936		273-773			21.42	Calculated composition (22.78 a/o Ni).
21	164	Svensson, B.	1936		273-773			30.20	Calculated composition (31.89 a/o Ni).
22	164	Svensson, B.	1936		273-773			39.71	Calculated composition (41.62 a/o Ni).
23	164	Svensson, B.	1936		273-773			49.80	Calculated composition (51.78 a/o Ni).

* Not shown in figure.

TABLE 23. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
24	184	Pollock, D.D. and Finch, D.I.	1956		288, 313			5.286	<0.008 Mg, <0.004 Si, and <0.001 each of others.
25*	184	Pollock, D.D. and Finch, D.I.	1956		288, 313			4.327	Similar to the above specimen.
26*	184	Pollock, D.D. and Finch, D.I.	1956		288, 313			3.101	Similar to the above specimen.
27*	184	Pollock, D.D. and Finch, D.I.	1956		288, 313			2.012	Similar to the above specimen.
28*	184	Pollock, D.D. and Finch, D.I.	1956		288, 313			1.029	Similar to the above specimen.
29	185	Mikryukov, V.E.	1956		312-830			0.90	0.18 Be; normalized.
30*	185	Mikryukov, V.E.	1956		343-830			0.62	0.14 Be; normalized.
31*	126	Linde, J.O.	1932		291			1.04	Calculated composition (1.12 a/o Ni); obtained from Kahlbaum; annealed at 800 C.
32*	126	Linde, J.O.	1932		291			2.00	Calculated composition (2.16 a/o Ni); obtained from Kahlbaum; annealed at 800 C.
33*	126	Linde, J.O.	1932		291			3.08	Calculated composition (3.32 a/o Ni); obtained from Kahlbaum; annealed at 800 C.
34	126	Linde, J.O.	1932		291			4.24	Calculated composition (4.57 a/o Ni); obtained from Hilger.
35	186	Kierspe, W.	1967	V	4.2-273			1.85	Calculated composition (2.0 a/o Ni); 3 mm diameter specimen.
36	187	Dutta-Roy, S.K. and Subrahmanyam, A.V.	1969	V	78-706			49.98	Calculated composition (51.96 a/o Ni); spectrographically pure; procured from Johnson Matthey and Co.; 30 x 6 x 0.3 mm^3; annealed for 24 h at 800 C in a vacuum furnace.
37	187	Dutta-Roy, S.K. and Subrahmanyam, A.V.	1969	V	79-688			39.99	Calculated composition (41.80 a/o Ni); similar to the above specimen.
38	172	Houghton, R.W., Sarachik, M.P., and Kouvel, J.S.	1970	A	1.75-80			28.37	Paramagnetic alloy; thin bar specimen; cut from cold-worked ingot, annealed and water-quenched.
39*	172	Houghton, R.W., et al.	1970	A	1.75-80			30.30	Similar to the above specimen.
40	172	Houghton, R.W., et al.	1970	A	1.75-80			32.25	Similar to the above specimen.
41*	172	Houghton, R.W., et al.	1970	A	1.75-80			34.20	Similar to the above specimen.
42*	172	Houghton, R.W., et al.	1970	A	1.75-80			36.16	Similar to the above specimen.
43*	172	Houghton, R.W., et al.	1970	A	1.75-80			38.12	Similar to the above specimen.
44*	172	Houghton, R.W., et al.	1970	A	1.75-80			40.09	Similar to the above specimen.
45	172	Houghton, R.W., et al.	1970	A	60-680			28.37	Calculated composition (30 a/o Ni).
46	172	Houghton, R.W., et al.	1970	A	50-680			32.25	Calculated composition (34 a/o Ni).
47*	172	Houghton, R.W., et al.	1970	A	50-680			36.16	Calculated composition (38 a/o Ni).

* Not shown in figure.

TABLE 23. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Composition (weight percent) Ni	Composition (continued), Specifications, and Remarks
48*	172	Houghton, R.W., Sarachik, M.P., and Kouvel, J.S.	1970	A	50-600			40.09	Calculated composition (42 a/o Ni).
49*	172	Houghton, R.W., et al.	1970	A	50-690			44.04	Calculated composition (46 a/o Ni).
50	172	Houghton, R.W., et al.	1970	A	50-690			48.02	Calculated composition (50 a/o Ni).
51*	171	Crangle, [illegible] and Butcher, P.J.L.	1970	A	5-294			45.43	Calculated composition (47.4 a/o Ni), prepared by melting together spectrographically pure Cu and Ni in an argon arc furnace and annealing the melts in vacuo for three days at above 1300 K, long, thin cylinder specimen accurately machined.
52	171	Crangle, J. and Butcher, P.J.L.	1970	A	6-294			42.75	Calculated composition (44.7 a/o Ni); similar to the above specimen.
53	171	Crangle, J. and Butcher, P.J.L.	1970	A	9-273			41.07	Calculated composition (43.0 a/o Ni); similar to the above specimen.
54*	171	Crangle, J. and Butcher, P.J.L.	1970	A	7-294			39.40	Calculated composition (41.3 a/o Ni); similar to the above specimen.
55*	171	Crangle, J. and Butcher, P.J.L.	1970	A	6-294			34.59	Calculated composition (36.4 a/o Ni); similar to the above specimen.
56	143	Schüle, W. and Kehrer, H.P.	1961	V	295-1273			28.37	Calculated composition (30 a/o Ni); 0.4 mm diameter wire specimen; prepared by melting the components in high frequency furnace under argon atmosphere; 90% deformed; measured during heating.
57*	143	Schüle, W. and Kehrer, H.P.	1961	V	319-1273			28.37	The above specimen measured during cooling.
58	143	Schüle, W. and Kehrer, H.P.	1961	V	308-1273			32.25	Calculated composition (34 a/o Ni); similar to the above specimen, measured during heating.
59*	143	Schüle, W. and Kehrer, H.P.	1961	V	311-1273			32.25	The above specimen measured during cooling.
60*	143	Schüle, W. and Kehrer, H.P.	1961	V	320-1273			35.67	Calculated composition (37.5 a/o Ni); similar to the above specimen; measured during heating.
61*	143	Schüle, W. and Kehrer, H.P.	1961	V	311-1273			35.67	The above specimen measured during cooling.
62*	143	Schüle, W. and Kehrer, H.P.	1961	V	295-1193			43.05	Calculated composition (45 a/o Ni); similar to the above specimen; measured during heating.
63*	143	Schüle, W. and Kehrer, H.P.	1961	V	295-1193			43.05	The above specimen measured during cooling.
64	188	Lecordier, J.C. and Colombani, A.	1968		298-820			9.5	Calculated composition (10.2 a/o Ni); film specimen prepared by evaporation and deposition at 1500 C.
65	188	Lecordier, J.C. and Colombani, A.	1968		300-839			16.1	Calculated composition (17.2 a/o Ni); similar to the above specimen.
66	188	Lecordier, J.C. and Colombani, A.	1968		300-9[illegible]0			23.7	Calculated composition (25.2 a/o Ni); similar to the above specimen.

* Not shown in figure.

TABLE 23. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
67*	188	Lecordier, J.C. and Colombani, A.	1968		303-897			32.1	Calculated composition (33.8 a/o Ni); similar to the above specimen.
68	188	Lecordier, J.C. and Colombani, A.	1968		297-900			32.9	Calculated composition (34.7 a/o Ni); similar to the above specimen.
69*	188	Lecordier, J.C. and Colombani, A.	1968		298-893			40.3	Calculated composition (42.2 a/o Ni); similar to the above specimen.
70*	188	Lecordier, J.C. and Colombani, A.	1968		299-896			47.8	Calculated composition (49.8 a/o Ni); similar to the above specimen.
71	64	Smith, C.S. and Palmer, E.W.	1935	B	293, 473	Bar 107	99.73	0.28	Specimen 0.75 in. in diameter and 8 in. long; supplied by American Brass Co.; annealed at 1073 K for 2 h; $d\rho/dT = 0.00315\ \mu\Omega\ cm\ K^{-1}$ at 253 K.
72*	64	Smith, C.S. and Palmer, E.W.	1935	B	293, 473	Bar 108	99.47	0.54	0.04 Mg and 0.02 Fe; similar to the above specimen; $d\rho/dT = 0.00270\ \mu\Omega\ cm\ K^{-1}$ at 293 K.
73*	64	Smith, C.S. and Palmer, E.W.	1935	B	293, 473	Bar 109	97.94	1.97	0.04 Mg and 0.02 Fe; similar to the above specimen except annealed at 800 C for 4 h; $d\rho/dT = 0.001613\ \mu\Omega\ cm\ K^{-1}$ at 293 K.
74	64	Smith, C.S. and Palmer, E.W.	1935	B	293, 473	Bar 110	94.92	5.09	0.03 Mg, and 0.01 Fe; similar to the above specimen; $d\rho/dT = 0.000912\ \mu\Omega\ cm\ K^{-1}$ at 293 K.
75*	64	Smith, C.S. and Palmer, E.W.	1935	B	293, 473	Bar 111	89.90	10.07	0.03 Mg, 0.024 C, and 0.02 Fe; similar to the above specimen; $d\rho/dT = 0.000524\ \mu\Omega\ cm\ K^{-1}$ at 293 K.
76	64	Smith, C.S. and Palmer, E.W.	1935	B	293, 473	Bar 125	84.85	15.07	0.05 Fe, 0.03, and 0.01 Mg; similar to the above specimen; $d\rho/dT = 0.000344\ \mu\Omega\ cm\ K^{-1}$ at 293 K.
77*	64	Smith, C.S. and Palmer, E.W.	1935	B	293, 473	Bar 124	69.54	30.23	0.013 Mn, 0.05 Fe, and 0.05 Mg; similar to the above specimen; $d\rho/dT = 0.000048\ \mu\Omega\ cm\ K^{-1}$ at 293 K.
78*	189	Sager, G.F.	1930	B	321-984		≈79.8	20.0	0.2 Mn, and trace Mg; 0.2 cm wire; chill cast, hot rolled and cold drawn; annealed at 700 C for 12 h.
79*	189	Sager, G.F.	1930	B	335-990		≈59.8	40.0	Similar to the above specimen.
80*	190	Barratt, T.	1914	B	279, 373	Eureka	60.0	40.0	0.0995 cm diameter x 28.14 cm long.
81	191	Gruneisen, E. and Goens, E.	1927		21-273	Cu11	99.0	1.0	Rod specimen.
82*	192	Jaeger, W. and Diesselhorst, H.	1900	B	291-373	Constantan	60.	40.	Density 8.92 g cm^{-3} at 18 C.
83	193, 194	Zimmerman, J.E. and Estermann, I.	1951		20-296	CN1	90.	10.	Machined from a forged bar supplied by Westinghouse.
84*	193, 194	Zimmerman, J.E. and Estermann, I.	1951		76-296	CN1	90.	10.	Cold worked by rolling from 0.25 in. thick to 0.14 in. before machined to size.
85*	193, 194	Zimmerman, J.E. and Estermann, E.	1951		79-298	CN3	90	10	Severely cold-worked.
86*	193, 194	Zimmerman, J.E. and Estermann, E.	1951		21-298	CN4	90	10	Single crystal.
87*	195	Berman, R.	1951		20-290	Constanton	60	40	Specimen consisted of 317 gauge 36 wires soldered together at ends.

* Not shown in figure.

TABLE 23. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
88*	196	Ellis, W.C., Morgan, F.L., and Sager, F.G.	1928	A	305	Advance	55.0	45.0	0.25 cm diameter x 2.64 cm long; density 8.73 g cm^{-3}.
89	130	Sedström, E.	1928		273, 373			10.1	Calculated composition (10.8 a/o Ni); prepared from Kahlbaum Cu and Ni; rolled and drawn to 1 mm thick; heated for 30 min. close to melting point.
90	130	Sedström, E.	1928		273, 373			20.1	Calculated composition (21.4 a/o Ni); similar to the above specimen.
91*	130	Sedström, E.	1928		273, 373			40.0	Calculated composition (41.9 a/o Ni); similar to the above specimen.
92*	197	Grüneisen, E.	1900		291		54	46	Density 8.89 g cm^{-3}.
93	198	Mikryukov, V.E.	1957		336-825			0.70	0.15 Co and 0.1 Be.
94	198	Mikryukov, V.E.	1957		333-900			0.90	0.10 Be and 0.10 Zr.
95	198	Mikryukov, V.E.	1957		336-947			0.80	0.20 Ti.
96*	198	Mikryukov, V.E.	1957		345-923			0.55	0.17 Zr.
97	199	Hulm, J.K.	1951		20-289		80	20	Average grain size 0.011 mm.
98*	200	Telkes, M.	1954		333-493	Constantan	60	40	Nominal composition.
99	201	Lerner, E. and Daunt, J.G.	1964	A	1.3-77	Advance	57	43	Nominal composition; 0.0015 in. wire specimen obtained from Driver-Harris Co.
100	202	Harvey, A.R., Legvold, S., and Peterson, D.T.	1971	A	2.1-35	$Cu_{0.94}Ni_{0.06}$		5.86	0.0143 Mn; calculated composition (6 a/o Ni); 0.040 in. diameter x 1 in. long; prepared from 99.99 pure Cu supplied by American Smelting and Refining Co. and 99.999 pure Ni supplied by Atomergic Chemetals Co. by arc-melting, swaging, and drawing; electropolished, annealed in vacuum at 1000 C for 3 days, then quenched in ice water.
101	202	Harvey, A.R., et al.	1971	A	2.1-35	$Cu_{0.94}Ni_{0.06}$		5.86	0.0296 Mn; similar to the above specimen.
102*	202	Harvey, A.R., et al.	1971	A	2.2-35	$Cu_{0.94}Ni_{0.06}$		5.86	0.0530 Mn; similar to the above specimen.
103	178	Legvold, S., Peterson, D.T., Burgardt, P., Hofer, R.J., Landell, B., and Vyrostek, T.A.	1974	A	3-283			11.3	Calculated composition (12.1 a/o Ni); 1 mm diameter x 5 in. long; 99.999 pure copper and 99.999 pure nickel from American Smelting and Refining Co. melted together, ingot swaged and drawn; annealed at 800 C for 3 days and quenched in ice-water.
104	178	Legvold, S., et al.	1974	A	4-297			20.96	Calculated composition (22.3 a/o Ni); similar to the above specimen.
105	178	Legvold, S., et al.	1974	A	5-296			31.18	Calculated composition (32.9 a/o Ni); similar to the above specimen.
106*	178	Legvold, S., et al.	1974	A	1-290			42.06	Calculated composition (44.0 a/o Ni); similar to the above specimen but quenched from 1000 C.
107*	178	Legvold, S., et al.	1974	A	5-291			42.06	The above specimen aged at room temperature for 3 years.
108*	178	Legvold, S., et al.	1974	A	5-297			42.06	The above specimen reannealed at 800 C for 3 days and quenched in ice-water.
109	141	Lengeler, B., Schilling, W., and Wenzl, H.	1970	V	4.2			0.925	Calculated composition (1.000 a/o Ni); wire specimen 150 to 270 μ thick and about 30 cm long supplied by DEGUSSA.

* Not shown in figure.

TABLE 23. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
110*	183	Chang, H.	1970	C	308-1065	Cupron special	55	45	Nominal composition; 0.1265 in. diameter x 0.992 in. long; reported error ±2%.
111	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			5.10	<0.00007 Fe; calculated composition (5.5 a/o Ni); 99.999⁺ pure Cu from American Smelting and Refining Co. and 99.999 pure Ni from Atomergic Chemetals Co. electron-beam melted separately under high vacuum, then arc-melted together in a graphite crucible, resulting fingers swaged and drawn into 0.014 in. wire, cut to 1 in. long and electro-polished; annealed in vacuum at 1000 C for 3 days, then quenched in ice water.
112	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			5.10	The above specimen measured in longitudinal magnetic fields ranging from 0.2 to 84 kOe.
113*	177	Eagen, C.F. and Legvold, S.	1972	A	2.9-40			5.10	0.0113 Cr and <0.00007 Fe; calculated composition (5.5 a/o Ni and 0.0138 a/o Cr); prepared from 99.999⁺ pure Cu from American Smelting and Refining Co., 99.999 pure Ni from Atomergic Chemetals Co., and 99.99⁺ pure Cr from Chromalloy Corp., same fabrication method and heat-treatment as the above specimen.
114*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			5.10	The above specimen measured in longitudinal magnetic fields ranging from 5.7 to 84 kOe.
115*	177	Eagen, C.F. and Legvold, S.	1972	A	2.4-55			5.10	0.0247 Cr and <0.00007 Fe; calculated composition (5.5 a/o Ni and 0.0301 a/o Cr); similar to the above specimen.
116	177	Eagen, C.F. and Legvold, S.	1972	A	4.2				The above specimen measured in longitudinal magnetic fields ranging from 12 to 85 kOe.
117*	177	Eagen, C.F. and Legvold, S.	1972	A	2.3-64			5.01	0.0530 Cr and <0.00007 Fe; calculated composition (5.4 a/o Ni and 0.0645 a/o Cr); similar to the above specimen.
118*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			5.01	The above specimen measured in longitudinal magnetic fields ranging from 8.6 to 84 kOe.
119	177	Eagen, C.F. and Legvold, S.	1972	A	2.2-90			5.10	0.0974 Cr and <0.00007 Fe; calculated composition (5.5 a/o Ni and 0.1185 a/o Cr); similar to the above specimen.
120*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			5.10	The above specimen measured in longitudinal magnetic fields ranging from 8.8 to 85 kOe.
121	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			11.94	<0.000065 Fe; calculated composition (12.8 a/o Ni); prepared from American Smelting and Refining Co. 99.999⁺ pure Cu and Atomergic Chemetals Co. 99.999 pure Ni by the same fabrication method and heat-treatment as the above specimen.
122*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			11.94	The above specimen measured in longitudinal magnetic fields ranging from 0.5 to 85 kOe.
123*	177	Eagen, C.F. and Legvold, S.	1972	A	3.4-38			11.76	0.0132 Cr and <0.000065 Fe; calculated composition (12.6 a/o Ni and 0.0160 a/o Cr); prepared from the same original Cu and Ni and chro-Chromalloy Co. 99.99⁺ pure Cr by the same fabrication method and heat-treatment as the above specimen.
124	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			11.76	The above specimen measured in longitudinal magnetic fields ranging from 6.6 to 84 kOe.

* Not shown in figure.

TABLE 23. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
125*	177	Eagen, C.F. and Legvold, S.	1972	A	2.8–43			11.85	0.0230 Cr and <0.000065 Fe; calculated composition (12.7 a/o Ni and 0.0278 a/o Cr); similar to the above specimen.
126*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			11.85	The above specimen measured in longitudinal magnetic fields ranging from 9.0 to 85 kOe.
127*	177	Eagen, C.F. and Legvold, S.	1972	A	3.5–51			11.76	0.0439 Cr and <0.000065 Fe; calculated composition (12.6 a/o Ni and 0.0531 a/o Cr); similar to the above specimen.
128*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			11.76	The above specimen measured in longitudinal magnetic fields ranging from 9.1 to 85 kOe.
129*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2–73			11.57	0.0996 Cr and <0.000065 Fe; calculated composition (12.4 a/o Ni and 0.1205 a/o Cr); similar to the above specimen.
130*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			11.57	The above specimen measured in longitudinal magnetic fields ranging from 9.4 to 85 kOe.
131*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			21.53	<0.000054 Fe; calculated composition (22.9 a/o Ni); prepared from American Smelting and Refining Co. 99.999+ pure Cu and Atomergic Chemetals Co. 99.999 pure Ni by the same fabrication method and heat-treatment as the above specimen.
132*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			21.53	The above specimen measured in longitudinal magnetic fields ranging from 9.4 to 85 kOe.
133*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2–31			21.53	0.0117 Cr and <0.000054 Fe; calculated composition (22.9 a/o Ni and 0.0140 a/o Cr); prepared from the same original Cu and Ni and Chromalloy Co. 99.99+ pure Cr by the same fabrication method and heat-treatment as the above specimen.
134*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			21.53	The above specimen measured in longitudinal magnetic fields ranging from 7.1 to 85 kOe.
135*	177	Eagen, C.F. and Legvold, S.	1972	A	3.0–36			21.54	0.0272 Cr and <0.000054 Fe; calculated composition (22.9 a/o Ni and 0.0327 Cr); similar to the above specimen.
136*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			21.54	The above specimen measured in longitudinal magnetic fields ranging from 13 to 85 kOe.
137*	177	Eagen, C.F. and Legvold, S.	1972	A	3.2–44			21.63	0.0515 Cr and <0.000054 Fe; calculated composition (23.0 a/o Ni and 0.0618 a/o Cr); similar to the above specimen.
138*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			21.63	The above specimen measured in longitudinal magnetic fields ranging from 7.2 to 85 kOe.
139*	177	Eagen, C.F. and Legvold, S.	1972	A	3.6–55			21.25	0.1007 Cr and <0.000054 Fe; calculated composition (22.6 a/o Ni and 0.1209 a/o Cr); similar to the above specimen.
140*	177	Eagen, C.F. and Legvold, S.	1972	A	4.2			21.25	The above specimen measured in longitudinal magnetic fields ranging from 6.1 to 85 kOe.
141	130	Sedström, E.	1919		273, 373			5.0	Calculated composition (5.4 a/o Ni); rolled and drawn to 1 mm in diameter; annealed at near melting point for 30 min.
142	130	Sedström, E.	1919		273, 373			30.4	Calculated composition (32.1 a/o Ni); similar to the above specimen.

* Not shown in figure.

TABLE 23. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
143	142	Köster, W. and Schüle, W.	1957		290–1173			30.0	Specimen deformed 70% into ribbon 0.1 mm thick; heated to 900 C for 30 min and furnace cooled.
144	142	Köster, W. and Schüle, W.	1957		287–1173			15.0	Specimen deformed 20% into ribbon 0.1 mm thick; heated to 900 C for 30 min and furnace cooled.
145	151	Ahmad, W.M. and Greig, D.	1974		293–873	Ni + 50% Cu	51.98	48.02	Composition given by authors as 50% Cu; composition not specified as at. or wt.% but review of other evidence, including comparison of resistivities with those of other investigators is most consistent with conclusion that compositions are at.%; prepared by M.J. Walker from Johnson-Matthey Spec-Pure Ni and Cu; pre-melted in argon arc followed by homogenization melt in quartz tubes; ingot rolled and drawn to wire of 0.5 mm diameter and about 120 cm length, cut to 10 cm length, and annealed in vacuum at 1223 K for about 24 hrs; resistivities accurate to better than 0.1% and temperatures to better than 1%; data extracted from tables.
146	151	Ahmad, W.M. and Greig, D.	1974		293–873	Ni + 60% Cu	61.89	38.11	Composition given by authors as 60% Cu; similar to the above specimen.
147	151	Ahmad, W.M. and Greig, D.	1974		293–873	Ni + 70% Cu	71.64	28.36	Composition given by authors as 70% Cu; similar to the above specimen.
148*	203	Los, G.J. and Gerritsen, A.N.	1957		1.42–273			0.023	Alloy prepared by Leiden Laboratory from pure components obtained from Johnson-Matthey and Co. Ltd. melted in vacuum radiation furnace. Ingot rolled and drawn into wire of desired diameter.
149	203	Los, G.J. and Gerritsen, A.N.	1957		1.42–273			0.14	Similar to the above specimen.
150	203	Los, G.J. and Gerritsen, A.N.	1957		1.42–273			0.72	Similar to the above specimen.
151	203	Los, G.J. and Gerritsen, A.N.	1957		1.42–273			2.06	Similar to the above specimen.
152	175	Ahmad, H.M. and Greig, D.	1974		6–908			33.22	Calculated composition (35 at.% Ni); no measurement information or specimen characterization; data extracted from figure.
153	176	Eagen, C.F.	1972		1.83–99.46			5.10	Composition given by author as 5.5 at.% Ni; prepared from 99.999+% pure Cu [<2.0 wt. ppm As, <2.0 Te, <1.0 Ni, <1.0 Pb, <1.0 S, <1.0 Sb, <1.0 Se, <1.0 Sn, <0.7 Fe, <0.5 Cr, <0.3 Ag, <0.1 Bi, and <0.1 wt. ppm Si] from American Smelting and Refining Co. and 99.999% pure Ni [<5.0 wt. ppm Si, 3.0 Fe, <1.0 Al, <1.0 Mg, 0.5 Ca, 0.5 Cd, 0.5 Cr, 0.5 Cu, 0.5 Pb, 0.1 Co, <0.1 C, and <0.1 wt. ppm S] from Atomergic Chemetals Co.; constituents electron-beam melted under high vacuum to remove volatile impurities, arc-melted together in graphite crucible, swaged and drawn through tungsten carbide die into wire of about 0.04 in. diameter, cut to about an inch in length, electropolished in 3 parts methanol to one part nitric acid, sealed in evacuated quartz ampoules, annealed for 3 days at 1273 K, and quenched as rapidly as possible in ice water; author believed annealing time and temperature resulted in no short-range ordering; data extracted from table.

* Not shown in figure.

TABLE 23. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Ni	Composition (continued), Specifications, and Remarks
154	176	Eagen, C. F.	1972		1.80–99			11.94	Composition given by author as 12.8 at.% Ni; similar to the above specimen.
155	176	Eagen, C. F.	1972		1.17–101			21.53	Composition given by author as 22.9 at.% Ni; similar to the above specimen.

TABLE 24. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

DATA SET 1

T	ρ
4.14	11.371
7.0	11.371
8.0	11.371*
11.2	11.371
17.9	11.361*
23.9	11.399
33.2	11.412
39.7	11.421*
45.3	11.450
50.2	11.473
54.6	11.512
59.7	11.547*
64.9	11.574
73.1	11.661
77.8	11.678*
80.9	11.669
180.3	12.487
274.2	13.262
300.6	13.409*
299.9	13.446
399.1	14.221
706.3	16.409
803.5	17.143
879.0	17.673
944.1	18.241
986.3	18.547
993.1	18.622*
1059.0	19.172*
1132.0	19.897

DATA SET 2

T	ρ
4.2	5.610
7.0	5.613
8.0	5.613*
11.1	5.618
17.7	5.623
23.4	5.629*
33.0	5.651
39.2	5.664*
44.6	5.693
50.2	5.721*
58.9	5.774
64.4	5.818*
70.6	5.878
76.9	5.890*

DATA SET 2 (cont.)

T	ρ
76.9	5.895*
196.3	6.873
270.4	7.436
298.5	7.611*
298.5	7.669*
449.8	8.755
563.6	9.495
657.7	10.057
744.7	10.921*
770.9	11.105
839.0	11.817*
897.4	12.123
933.3	12.478*
1030.0	13.250*
1057.0	13.508
1091.0	13.840*
1140.0	14.278*
1140.0	14.299*
1164.0	14.566

DATA SET 3

T	ρ
4.2	2.289
6.6	2.289
10.9	2.289
17.5	2.294
23.6	2.304
32.1	2.316
38.6	2.328*
44.8	2.338
48.2	2.373*
54.1	2.406
59.4	2.485*
63.8	2.482
70.6	2.530*
76.2	2.561*
186.6	3.420
194.1	3.470*
215.3	3.618
241.5	3.808*
268.5	3.978
298.5	4.183
386.4	4.818
492.0	5.530
502.3	5.719*
522.4	5.819*

DATA SET 3 (cont.)

T	ρ
597.0	6.346
666.8	6.670
779.8	7.766
845.3	8.292
905.7	8.755
939.7	9.054*
993.1	9.504
1040.0	10.013*
1047.0	9.990*
1107.0	10.593
1172.0	11.143

DATA SET 4

T	ρ
4.2	4.21
15	4.21
30	4.24
40	4.27
50	4.32
60	4.38
90	4.59
120	4.84
150	5.08
180	5.30
210	5.51
240	5.72

DATA SET 5

T	ρ
4.2	19.45
15	19.45
30	19.48
40	19.52
50	19.58
60	19.65
90	19.92
120	20.22
150	20.50
180	20.78
210	21.05
240	21.34

DATA SET 6

T	ρ
4.2	11.59*
15	11.60

DATA SET 6 (cont.)

T	ρ
30	11.61
40	11.64
50	11.69
60	11.76
90	12.02
120	12.27
150	12.52
180	12.78
210	13.03
240	13.30

DATA SET 7

T	ρ
4.2	1.12*
15	1.12
30	1.14
40	1.16
50	1.20
60	1.25
90	1.46
120	1.68
150	1.89
180	2.11
210	2.33
240	2.54

DATA SET 8

T	ρ
10	1.3217

DATA SET 9

T	ρ
73.2	42.4
123.2	43.0
173.2	43.5
223.2	43.9
273.2	44.1
373.2	44.6
673.2	44.8

DATA SET 10

T	ρ
90.2	1.675
95.5	1.714
111.0	1.825
167.4	2.240

DATA SET 10 (cont.)

T	ρ
193.2	2.408
217.7	2.585
233.1	2.680*
273.2	2.961
295.7	3.124

DATA SET 11

T	ρ
90.2	2.870
95.7	2.918*
111.2	3.041
167.5	3.460
193.5	3.638*
217.7	3.812
232.7	3.913*
273.2	4.203
295.5	4.367

DATA SET 12

T	ρ
90.2	4.101
96.0	4.166*
111.4	4.280
167.7	4.727
193.8	4.921*
217.7	5.094
232.2	5.192*
273.2	5.496
295.5	5.670

DATA SET 13

T	ρ
1.5	43.809
2.3	43.811
2.5	43.816*
2.7	43.833*
3.3	43.865
3.6	43.884*
4.0	43.908*
4.9	43.938
4.9	43.947*
5.7	43.991*
6.5	44.017*
8.6	44.101
10.8	44.161*
13.5	44.174*

DATA SET 13 (cont.)

T	ρ
16.5	44.178*
17.9	44.179*
20.7	44.176
24.1	44.170*
29.8	44.136*
32.3	44.153
35.4	44.147*
37.0	44.145*
39.6	44.139*
41.6	44.139
45.8	44.141
49.0	44.140*
50.7	44.144
53.7	44.147*
58.0	44.155*
63.2	44.168

DATA SET 14*

T	ρ
2.0	44.978
3.5	44.979
4.5	44.980
4.8	44.985
4.9	44.990
4.9	44.997
5.4	45.038
6.3	45.141
7.8	45.293
8.9	45.299
10.1	45.294
11.1	45.288
12.5	45.278
16.0	45.255
17.9	45.235
20.2	45.221
22.1	45.209
25.0	45.185
27.2	45.164
34.0	45.113
38.2	45.080
42.4	45.038
47.0	45.035
49.8	45.032
53.4	45.024
55.6	45.021
59.4	45.021

* Not shown in figure.

TABLE 24. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 14 (cont.)*	
61.8	45.024
64.3	45.026
68.0	45.031
DATA SET 15	
11	45.97
25	46.96
30	47.20
40	47.51
50	47.73
60	47.90
70	48.02*
80	48.15
90	48.27*
100	48.36
110	48.45*
120	48.52*
130	48.60
140	48.67*
150	48.71*
170	48.79*
180	48.83*
200	48.89
225	48.93*
250	48.99*
300	49.00
350	49.00*
372	49.00
DATA SET 16*	
298.2	48.95
DATA SET 17	
298.2	48.05
DATA SET 18*	
298.2	46.20
DATA SET 19	
273.2	14.48*
323.2	14.81
373.2	15.14*
423.2	15.48*
DATA SET 19 (cont.)	
473.2	15.82*
523.2	16.15*
573.2	16.49*
623.2	16.82*
673.2	17.16*
723.2	17.49*
773.2	17.83*
DATA SET 20	
273.2	27.31
323.2	27.64
373.2	27.92
423.2	28.16*
473.2	28.40
523.2	28.62*
573.2	28.85
623.2	29.08*
673.2	29.31
723.2	29.53*
773.2	29.78
DATA SET 21	
273.2	37.70
323.2	38.01*
373.2	38.22
423.2	38.44*
473.2	38.65
523.2	38.86*
573.2	39.07
623.2	39.28*
673.2	39.50
723.2	39.72*
773.2	39.94
DATA SET 22	
273.2	47.13
323.2	47.07*
373.2	47.00
423.2	46.89*
473.2	46.85
523.2	46.86*
573.2	46.99
623.2	47.19*
673.2	47.48
723.2	47.81*
773.2	48.17
DATA SET 23	
273.2	52.55
323.2	52.53*
373.2	52.50
423.2	52.47*
473.2	52.41
523.2	52.42*
573.2	52.49
623.2	52.71*
673.2	53.13
723.2	53.59*
773.2	53.99
DATA SET 24	
288	8.02
313	8.10
DATA SET 25*	
288	6.80
313	6.90
DATA SET 26*	
288	5.30
313	5.35
DATA SET 27*	
288	4.15
313	4.20
DATA SET 28*	
288	2.93
313	3.07
DATA SET 29	
312	4.01
345	4.33
395	4.75
505	5.58
600	6.15
715	6.35
760	6.48
830	6.90
DATA SET 30*	
343	3.61
417	4.10
475	4.48
575	5.10
640	5.45
765	6.22
830	6.70
DATA SET 31*	
291.2	3.085
DATA SET 32*	
291.2	4.333
DATA SET 33*	
291.2	5.632
DATA SET 34	
291.2	6.949
DATA SET 35	
4.2	2.2466
10	2.2492
20	2.2521
30	2.2662
40	2.2993
50	2.3492
70	2.4812
83	2.5802
103	2.7301
123	2.8818
143	3.0326
163	3.1811
183	3.3266
203	3.4710
223	3.6146*
243	3.7563
263	3.8972*
273	3.9674
DATA SET 36	
78	64.4
DATA SET 36 (cont.)	
300	65.0
385	64.8
457	64.6
531	64.0
631	64.2
706	65.0
DATA SET 37	
79	56.7
301	57.0
383	57.6
450	56.5
604	55.7
688	57.7
DATA SET 38	
1.75	34.4
10	34.4
20	34.3
30	34.4
40	34.4
50	34.4
60	34.5
70	34.6
80	34.7
DATA SET 39*	
1.75	37.5
10	37.5
20	37.5
30	37.4
40	37.4
50	37.5
60	37.5
70	37.6
80	37.7
DATA SET 40	
1.75	39.5
10	39.4
20	39.3
30	39.3
40	39.3
50	39.3
DATA SET 40 (cont.)	
60	39.4
70	39.5
80	39.6
DATA SET 41*	
1.75	42.6
10	42.5
20	42.4
30	42.3
40	42.3
50	42.3
60	42.3
70	42.3
80	42.4
DATA SET 42*	
1.75	44.3
10	44.2
20	44.1
30	44.0
40	43.9
50	43.9
60	43.9
70	44.0
80	44.0
DATA SET 43*	
1.75	45.8
10	45.6
20	45.5
30	45.4
40	45.3
50	45.2
60	45.1
70	45.1
80	45.1
DATA SET 44*	
1.75	47.1
10	47.0
20	46.9
30	46.7
40	46.6
50	46.6

* Not shown in figure.

TABLE 24. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

DATA SET 44 (cont.)*

T	ρ
60	46.5
70	46.5
80	46.5

DATA SET 45

T	ρ
60	34.5*
100	34.8
150	35.3
200	35.6
250	35.8
300	36.1
350	36.2
400	36.4
450	36.5*
500	36.6
550	36.8*
600	37.0
680	37.3

DATA SET 46

T	ρ
50	39.3*
100	39.7
150	40.1
200	40.3
250	40.4
300	40.5
350	40.5*
400	40.5
450	40.5*
500	40.5
530	40.5*
600	40.6
680	41.0

DATA SET 47*

T	ρ
50	43.9
100	44.0
150	44.2
200	44.3
250	44.2
300	44.1
350	44.0
400	43.9
450	43.8
500	43.7

DATA SET 47 (cont.)*

T	ρ
550	43.6
600	43.5
680	43.8

DATA SET 48*

T	ρ
50	46.5
100	46.5
150	46.5
200	46.4
250	46.1
300	45.9
350	45.6
400	45.5
450	45.2
500	45.0
550	44.8
600	44.8

DATA SET 49*

T	ρ
50	49.4
100	49.4
150	49.4
200	49.3
250	49.0
300	48.7
350	48.5
400	48.3
450	48.0
500	47.7
550	47.2
600	47.0
690	47.5

DATA SET 50

T	ρ
0	50.95*
50	52.5
100	52.9
150	53.0
200	52.9
250	52.7
300	52.5
350	52.2*
400	52.0
450	51.6*
500	51.2

DATA SET 50 (cont.)

T	ρ
550	51.0*
600	50.8
690	51.0

DATA SET 51*

T	ρ
5	47.2
13	47.5
20	47.6
31	47.7
40	47.6
50	47.6
59	47.6
75	47.7
92	47.8
104	47.8
172	48.2
188	48.2
211	48.3
224	48.4
294	48.6

DATA SET 52

T	ρ
6	46.3
17	46.1
30	46.0
44	45.8
59	45.8
95	45.9
119	45.9*
137	46.1
156	46.2*
178	46.2*
189	46.3
203	46.3*
219	46.4*
234	46.4
257	46.6*
294	46.7

DATA SET 53

T	ρ
9	45.8
19	45.7
38	45.5
52	45.4*
81	45.4

DATA SET 53 (cont.)

T	ρ
110	45.5
149	45.7*
173	45.8

DATA SET 54*

T	ρ
7	44.6
17	44.4
31	44.2
63	44.2
78	44.2
98	44.6
133	44.7
150	44.6
172	44.9
198	44.9
224	45.1
294	45.4

DATA SET 55*

T	ρ
6	39.1
20	39.1
33	38.9
41	38.9
61	39.0
77	39.1
90	39.3
124	39.5
150	39.9
181	40.2
203	40.3
226	40.7
294	41.5

DATA SET 56

T	ρ
295.2	36.88
386.2	37.13
474.2	37.30
515.2	37.35*
559.2	37.35
604.2	37.29*
638.2	37.13*
673.2	36.88*
713.2	36.79*
746.2	36.79
776.2	36.86*

DATA SET 56 (cont.)

T	ρ
806.2	37.00*
873.2	37.32
957.2	37.64*
1028.2	37.98
1073.2	38.23*
1156.2	38.74
1213.2	39.15*
1273.2	39.65

DATA SET 57*

T	ρ
319.2	35.91
401.2	36.10
473.2	36.24
607.2	36.43
674.2	36.62
800.2	37.10
873.2	37.34
957.2	37.64
1028.2	37.98
1073.2	38.23
1156.2	38.74
1213.2	39.15
1273.2	39.65

DATA SET 58

T	ρ
308.2	45.03
473.2	44.84
527.2	44.69*
574.2	44.45
632.2	43.93*
673.2	43.72
717.2	43.60*
759.2	43.60
796.2	43.64*
873.2	43.94
990.2	44.46
1074.2	44.92*
1173.2	45.61*
1225.2	46.01
1273.2	46.42

DATA SET 59*

T	ρ
311.2	43.44
384.2	43.33
473.2	43.21

DATA SET 59 (cont.)*

T	ρ
531.2	43.15
579.2	43.15
673.2	43.31
763.2	43.54
796.2	43.64
873.2	43.94
990.2	44.46
1074.2	44.92
1173.2	45.61
1225.2	46.01
1273.2	46.42

DATA SET 60*

T	ρ
320.2	46.33
364.2	46.15
403.2	46.08
473.2	46.00
523.2	45.84
568.2	45.65
639.2	45.08
673.2	44.90
712.2	44.78
767.2	44.78
823.2	44.96
873.2	45.16
1007.2	45.77
1073.2	46.13
1159.2	46.64
1217.2	47.14
1273.2	47.67

DATA SET 61*

T	ρ
311.2	45.11
472.2	44.79
580.2	44.58
655.2	44.58
696.2	44.63
767.2	44.78
823.2	44.96
873.2	45.16
1007.2	45.77
1073.2	46.13
1159.2	46.64
1217.1	47.14
1273.2	47.67

* Not shown in figure.

TABLE 24. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

DATA SET 62*

T	ρ
295.2	48.40
474.2	46.98
583.2	45.85
627.2	45.36
651.2	45.27
673.2	45.27
873.2	45.86
980.2	46.32
1073.2	46.84
1193.2	47.58

DATA SET 63*

T	ρ
295.2	46.67
333.2	46.55
370.2	46.48
414.2	46.26
472.2	45.86
535.2	45.53
553.2	45.32
619.2	45.23
645.2	45.23
673.2	45.27
873.2	45.86
980.2	46.32
1073.2	46.84
1193.2	47.58

DATA SET 64

T	ρ
298	15.8
443	16.8
503	17.2
605	17.9
675	18.4
733	18.7
820	19.3

DATA SET 65

T	ρ
300	23.6
410	24.2
533	24.8
605	25.3
671	25.6
734	25.9
839	26.6

DATA SET 66

T	ρ
300	30.9
350	31.1
460	31.6
523	31.8
604	32.0
676	32.2
746	32.5*
817	32.8*
900	33.3

DATA SET 67*

T	ρ
303	38.4
413	38.4
478	38.5
531	38.5
605	38.6
676	38.6
744	38.8
800	38.9
897	39.2

DATA SET 68

T	ρ
297	42.1
403	42.1
470	42.1
534	42.1
603	42.1
674	42.1*
747	42.2*
806	42.4
900	42.6

DATA SET 69*

T	ρ
298	46.3
399	45.9
467	45.7
526	45.5
602	45.4
670	45.4
744	45.4
812	45.5
893	45.7

DATA SET 70*

T	ρ
299	50.2
391	49.9
470	49.8
537	49.6
610	49.5
678	49.5
749	49.6
822	49.9
896	50.2

DATA SET 71

T	ρ
293.2	2.19
473.2	3.44

DATA SET 72*

T	ρ
293.2	2.50
473.2	3.72

DATA SET 73*

T	ρ
293.2	4.40
473.2	5.69

DATA SET 74

T	ρ
293.2	8.07
473.2	9.40

DATA SET 75*

T	ρ
293.2	14.14
473.2	15.48

DATA SET 76

T	ρ
293.2	19.63
473.2	20.86

DATA SET 77*

T	ρ
293.2	36.31
473.2	36.63

DATA SET 78*

T	ρ
321.2	28.25
423.2	28.90
588.2	30.03
735.2	31.15
848.2	32.05
984.2	33.11

DATA SET 79*

T	ρ
335.2	50.25
539.2	50.25
783.2	51.02
990.2	52.08

DATA SET 80*

T	ρ
279.16	45.90
372.64	45.87

DATA SET 81

T	ρ
21.2	1.295
83.2	1.60
273.2	2.97

DATA SET 82*

T	ρ
291.2	49.0
373.2	49.1

DATA SET 83

T	ρ
19.7	12.50
78.9	12.72
296	14.68

DATA SET 84*

T	ρ
76.2	12.66
296	14.69

DATA SET 85*

T	ρ
78.7	12.63
296	14.65

DATA SET 86*

T	ρ
20.5	13.0
79.3	13.10
298	15.04

DATA SET 87*

T	ρ
20	44.3
90	45.3
290	52.7

DATA SET 88*

T	ρ
305.2	49.43

DATA SET 89

T	ρ
273.2	16.13
373.2	16.39

DATA SET 90

T	ρ
273.2	28.57
373.2	30.30

DATA SET 91*

T	ρ
273.2	50.0
373.2	50.0

DATA SET 92*

T	ρ
291.2	50.3

DATA SET 93

T	ρ
336.2	3.88
387.8	4.33
468.2	4.90
546.2	5.48
649.0	6.06
706.7	6.38
824.5	6.98

DATA SET 94

T	ρ
332.6	3.34
388.8	3.85

DATA SET 94 (cont.)

T	ρ
444.7	4.33
564.8	5.21
638.8	5.78
730.2	6.33
807.7	7.05
899.7	8.14

DATA SET 95

T	ρ
336.0	4.25
404.1	4.88
490.7	5.56
563.8	6.01
735.7	6.46
713.5	6.57
853.5	7.18
811.5	7.28
891.2	8.93
946.8	9.78

DATA SET 96

T	ρ
345.0	3.45
431.9	4.13
474.2	4.43
564.2	5.10
604.2	5.32
674.6	5.78
746.8	6.20
808.0	6.83
848.2	7.20
922.7	8.07

DATA SET 97

T	ρ
20.4	23.3
79.0	23.9
289	25.9

DATA SET 98*

T	ρ
333	49
383	49
493	49

* Not shown in figure.

TABLE 24. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 99	
1.3	25.78
1.7	25.79
2.3	25.80
2.5	25.81
3.1	25.82
3.7	25.84*
4.3	25.85
63.2	27.05
76.9	27.14
DATA SET 100	
2.1	6.500
2.4	6.549
3.0	6.548
3.5	6.540*
6.4	6.546
7.5	6.5456
8.5	6.5455
9.9	6.5447
11.7	6.5446*
13.5	6.5446
14.7	6.5451*
18.1	6.5459*
20.4	6.5487
23.1	6.5533*
26.7	6.5564
29.9	6.5602*
35.2	6.5726
DATA SET 101*	
2.1	6.6255
2.3	6.6245
3.0	6.6236
3.6	6.6228
6.4	6.6189
7.7	6.6174
8.5	6.6170
9.9	6.6153
11.6	6.6144
13.5	6.6138
14.8	6.6138
18.1	6.6132
20.4	6.6156
23.2	6.6194
26.7	6.6220
29.8	6.6296
35.3	6.6408

T	ρ
DATA SET 102*	
2.2	6.7138
2.5	6.7128
2.9	6.7117
3.7	6.7103
6.4	6.7051
7.6	6.7027
8.6	6.7014
10.0	6.6992
11.7	6.6967
13.3	6.6949
14.7	6.6949
18.1	6.6932
20.3	6.6937
23.2	6.6950
26.7	6.6991
29.8	6.7042
35.2	6.7128
DATA SET 103	
3	13.93
11	13.94
20	13.94
38	13.99
60	14.09
77	14.24
89	14.31
156	14.85
163	14.89*
168	14.93*
175	14.99
180	15.04*
188	15.06*
196	15.15*
203	15.22*
209	15.26
217	15.31*
225	15.37*
232	15.45
241	15.51*
248	15.55*
253	15.61*
262	15.67
278	15.79*
283	15.85
DATA SET 104	
4	24.67

T	ρ
DATA SET 104 (cont.)	
10	24.67
15	24.69
23	24.71
32	24.72
46	24.78
77	25.07
93	25.24
118	25.56*
128	25.64
142	25.79
155	25.88
162	25.94*
173	26.02*
178	26.09*
191	26.19
203	26.26*
212	26.35*
223	26.41*
230	26.49
238	26.51*
245	26.59*
251	26.65*
263	26.75
270	26.79*
278	26.83*
297	26.97
DATA SET 105	
5	36.70
21	36.70
30	36.69
42	36.75
60	36.90
78	37.09
115	37.47
130	37.54*
155	37.66
170	37.78*
183	37.86*
192	37.94*
203	37.98
213	38.02*
223	38.09*
233	38.17*
242	38.22*
250	38.24
262	38.33*
270	38.38*

T	ρ
DATA SET 105 (cont.)	
277	38.44*
296	38.54
DATA SET 106*	
1	48.23
4	48.19
7	48.17
10	48.13
15	48.07
20	48.01
23	47.96
28	47.89
35	47.82
42	47.78
46	47.76
50	47.74
55	47.73
78	47.69
290	47.91
DATA SET 107*	
5	47.75
77	47.37
89	47.50
100	47.57
106	47.63
126	47.50
143	47.40
157	47.34
169	47.28
202	47.23
222	47.16
238	47.11
250	47.06
259	47.00
272	46.95
279	46.92
285	46.89
288	46.88
291	46.85
DATA SET 108*	
5	48.54
12	48.44
21	48.33
30	48.23

T	ρ
DATA SET 108 (cont.)*	
41	48.06
60	47.99
76	47.93
99	47.84
108	47.80
120	47.78
129	47.80
143	47.80
152	47.80
157	47.79
168	47.76
184	47.74
198	47.71
212	47.65
220	47.64
230	47.65
285	47.46
297	47.43
DATA SET 109	
4.2	1.137
DATA SET 110*	
308	46.02
313	46.02
317	46.02
358	45.37
365	45.69
373	45.05
410	45.05
435	44.73
487	44.73
527	44.41
568	44.09
573	44.09
621	44.09
667	44.09
710	44.09
711	44.09
753	44.09
792	44.41
831	44.41
862	44.41
866	44.41
900	44.73
935	44.73
970	45.05

T	ρ
DATA SET 110 (cont.)*	
1004	45.05
1005	45.37
1065	45.69
DATA SET 111	
4.2	5.98
H(kOe)	**ρ**
DATA SET 112 (T = 4.2 K)	
0.2	5.980*
5.9	5.980
12.5	5.980
18.9	5.980
27.6	5.980
35.7	5.981
43.4	5.981
51.9	5.982*
59.3	5.982
66.2	5.982*
71.9	5.983*
78.5	5.984*
83.8	5.984
T	**ρ**
DATA SET 113*	
2.9	6.116
3.7	6.113
4.2	6.110
4.7	6.109
5.2	6.106
6.0	6.103
7.3	6.099
8.4	6.096
11.9	6.090
15.8	6.085
18.0	6.083
19.7	6.081
24.0	6.081
27.6	6.084
32.7	6.091
39.7	6.111

* Not shown in figure.

TABLE 24. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

DATA SET 114* (T = 4.2 K)

H(kOe)	ρ
3.7	6.110
19.1	6.109
27.4	6.108
35.3	6.107
43.3	6.106
51.7	6.105
59.0	6.103
66.3	6.102
72.1	6.102
78.6	6.101
84.2	6.100

DATA SET 115*

T	ρ
2.4	6.244
2.9	6.237
4.2	6.230
4.4	6.222
4.7	6.220
5.1	6.214
6.6	6.205
7.8	6.199
11.2	6.185
15.1	6.172
19.0	6.163
23.3	6.158
26.9	6.158
32.1	6.161
39.1	6.177
47.3	6.208
54.7	6.244

DATA SET 116 (T = 4.2 K)

H(kOe)	ρ
12.4	6.229
19.1	6.227
27.2	6.225*
35.1	6.223
43.5	6.220*
51.5	6.217*
59.4	6.214*
66.1	6.211

DATA SET 116 (cont.) (T = 2 K)

H(kOe)	ρ
72.7	6.209*
79.3	6.207*
84.6	6.205

DATA SET 117*

T	ρ
2.3	6.425
2.8	6.416
4.2	6.400
5.0	6.387
6.6	6.372
8.2	6.360
9.9	6.350
10.7	6.345
12.1	6.339
13.6	6.332
15.6	6.323
17.6	6.315
18.7	6.313
20.5	6.308
24.0	6.300
26.7	6.296
30.8	6.296
34.6	6.297
39.7	6.309
42.9	6.319
46.2	6.330
51.9	6.352
58.0	6.380
64.2	6.410

DATA SET 118* (T = 4.2 K)

H(kOe)	ρ
8.6	6.400
15.4	6.398
24.4	6.394
34.7	6.390
44.6	6.384
54.8	6.379
65.1	6.373
75.0	6.368
84.4	6.363

DATA SET 119

T	ρ
2.2	6.978
3.3	6.965
4.2	6.950*
5.2	6.936
6.8	6.914*
8.8	6.894
10.5	6.879
12.2	6.861*
13.9	6.850*
16.1	6.830
18.3	6.821*
20.5	6.807
24.6	6.786*
26.9	6.779*
31.0	6.773
34.8	6.771*
40.2	6.775
43.2	6.781*
45.9	6.786*
52.0	6.804
58.3	6.827*
64.5	6.850
72.6	6.890*
79.5	6.925*
89.6	6.987

DATA SET 120* (T = 4.2 K)

H(kOe)	ρ
8.8	6.949
14.9	6.946
24.4	6.941
34.9	6.934
44.8	6.926
54.7	6.918
64.6	6.909
75.2	6.899
85.3	6.890

DATA SET 121

T	ρ
4.2	14.0

DATA SET 122* (T = 4.2 K)

H(kOe)	ρ
0.5	14.000
6.3	14.000
12.9	14.000
17.8	14.000
25.8	14.001
34.1	14.001
42.6	14.001
50.7	14.001
59.1	14.002
66.3	14.002
73.0	14.002
79.4	14.003
84.8	14.004

DATA SET 123*

T	ρ
3.4	14.000
4.2	14.000
4.3	13.999
5.1	13.998
5.8	13.996
6.9	13.995
8.3	13.992
10.6	13.989
13.6	13.985
16.9	13.982
19.7	13.980
21.3	13.979
24.7	13.979
28.4	13.983
32.7	13.990
37.9	14.005

DATA SET 124 (T = 4.2 K)

H(kOe)	ρ
6.6	14.000
11.7	14.000
17.9	14.000
25.9	14.000
34.4	14.001
42.9	14.001*
50.6	14.002

DATA SET 124 (cont.) (T = 4.2 K)

H(kOe)	ρ
58.9	14.002*
66.2	14.003
73.1	14.003*
79.5	14.004*
84.4	14.004

DATA SET 125*

T	ρ
2.8	14.006
3.3	14.004
3.8	14.002
4.2	14.000
5.1	13.997
7.0	13.992
8.9	13.988
10.1	13.985
11.1	13.982
12.2	13.981
13.8	13.979
16.0	13.975
18.0	13.972
20.6	13.970
24.3	13.968
26.5	13.968
30.4	13.971
34.7	13.976
40.1	13.995
43.2	14.009

DATA SET 126* (T = 4.2 K)

H(kOe)	ρ
9.0	14.000
15.7	14.000
25.0	14.001
35.3	14.002
45.3	14.003
55.3	14.005
65.4	14.006
75.4	14.008
85.4	14.010

DATA SET 127*

T	ρ
3.5	14.004
4.2	14.000
4.8	13.996
6.0	13.992
7.5	13.985
9.9	13.975
12.9	13.967
16.1	13.957
18.8	13.950
20.7	13.946
24.1	13.943
27.9	13.943
32.2	13.945
37.4	13.955
42.5	13.973
46.7	13.992
50.8	14.014

DATA SET 128* (T = 4.2 K)

H(kOe)	ρ
9.1	14.000
15.9	13.999
24.7	13.998
35.2	13.996
45.4	13.993
55.2	13.991
65.5	13.988
75.6	13.985
85.2	13.981

DATA SET 129*

T	ρ
4.2	14.000
5.1	13.990
5.8	13.981
6.7	13.965
8.8	13.951
10.6	13.940
11.5	13.935
12.3	13.925
13.7	13.919
16.3	13.904
18.2	13.894

* Not shown in figure.

TABLE 24. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

DATA SET 129 (cont.)*

T	ρ
20.8	13.882
24.7	13.870
27.0	13.866
30.7	13.860
35.0	13.858
40.1	13.863
43.9	13.877
52.0	13.900
58.2	13.923
64.3	13.952
72.8	13.990

DATA SET 130* (T = 4.2 K)

H(kOe)	ρ
9.4	13.999
15.4	13.998
24.9	13.995
35.4	13.991
45.2	13.985
55.1	13.980
65.3	13.974
75.6	13.967
85.3	13.961

DATA SET 131*

T	ρ
4.2	25.3

DATA SET 132* (T = 4.2 K)

H(kOe)	ρ
0.3	25.300
6.8	25.301
12.7	25.301
18.6	25.301
25.9	25.302
33.0	25.302
40.3	25.302
47.1	25.302
54.4	25.302
61.1	25.303

DATA SET 132 (cont.)* (T = 4.2 K)

H(kOe)	ρ
68.8	25.303
75.2	25.303
80.1	25.303
85.1	25.304

DATA SET 133*

T	ρ
4.2	25.300
5.4	25.299
6.6	25.299
7.8	25.298
9.6	25.297
11.1	25.296
13.4	25.295
16.0	25.294
19.2	25.293
21.4	25.293
22.4	25.293
25.4	25.296
28.4	25.298
30.8	25.303

DATA SET 134* (T = 4.2 K)

H(kOe)	ρ
7.1	25.300
18.7	25.301
26.2	25.301
33.2	25.301
40.4	25.301
47.0	25.301
54.6	25.301
61.2	25.300
68.5	25.300
75.0	25.300
80.3	25.300
85.2	25.300

DATA SET 135*

T	ρ
3.0	25.301

DATA SET 135 (cont.)*

T	ρ
4.2	25.300
5.0	25.298
6.9	25.296
9.6	25.293
10.2	25.291
11.4	25.291
13.7	25.288
17.2	25.286
21.3	25.283
24.4	25.283
27.8	25.285
31.8	25.293
36.1	25.304

DATA SET 136* (T = 4.2 K)

H(kOe)	ρ
12.9	25.301
18.7	25.301
26.0	25.301
33.1	25.301
40.3	25.300
46.9	25.300
54.4	25.300
61.1	25.299
68.6	25.299
75.1	25.299
80.1	25.298
85.2	25.298

DATA SET 137*

T	ρ
3.2	25.302
4.2	25.300
4.6	25.296
6.7	25.293
9.2	25.286
11.1	25.283
13.7	25.277
17.2	25.271
21.0	25.267
24.2	25.265
27.8	25.265
32.2	25.270

DATA SET 137 (cont.)*

T	ρ
36.1	25.278
39.1	25.288
42.3	25.302
43.8	25.309

DATA SET 138* (T = 4.2 K)

H(kOe)	ρ
7.2	25.300
12.9	25.301
18.7	25.301
26.0	25.300
33.0	25.300
40.3	25.299
47.1	25.298
54.5	25.297
61.2	25.297
68.7	25.295
75.2	25.294
80.2	25.294
85.2	25.293

DATA SET 139*

T	ρ
3.6	25.305
4.2	25.300
5.8	25.292
7.5	25.283
9.0	25.276
10.6	25.270
12.8	25.260
15.5	25.252
18.4	25.242
21.0	25.235
22.3	25.232
25.6	25.226
27.6	25.225
29.9	25.224
33.3	25.226
36.0	25.230
39.5	25.237
43.0	25.247
45.3	25.258
47.8	25.269

DATA SET 139 (cont.)*

T	ρ
49.7	25.277
55.1	25.305

DATA SET 140* (T = 4.2 K)

H(kOe)	ρ
6.1	25.300
12.8	25.300
19.6	25.299
27.6	25.298
35.8	25.297
44.0	25.296
52.3	25.294
60.0	25.292
67.2	25.290
73.4	25.288
79.7	25.286
85.2	25.283

DATA SET 141

T	ρ
273.2	8.40
373.2	9.43

DATA SET 142

T	ρ
273.2	35.7
373.2	43.5

DATA SET 143

T	ρ
290	43.35
473	43.35
573	43.35
673	43.40*
773	43.67
873	43.84*
973	43.89
1073	43.89
1173	43.89

DATA SET 144

T	ρ
287	44.32*

DATA SET 144 (cont.)

T	ρ
473	44.31*
573	44.36*
673	44.50*
773	44.80
873	45.51
973	45.63
1073	45.63
1173	45.63*

DATA SET 145

T	ρ
293	49.99
333	49.76*
373	49.53*
433	49.19
473	48.98
533	48.71
573	48.56
673	48.25
773	48.39*
873	48.65

DATA SET 146

T	ρ
293	43.84*
333	43.67
373	43.50*
433	43.25
473	43.11*
533	42.90*
573	42.77*
673	42.55
773	42.63
873	42.69

DATA SET 147

T	ρ
293	35.00
333	35.10
373	35.19
433	35.27
473	35.31
533	35.38
573	35.42
673	35.50
773	35.75
873	36.06

* Not shown in figure.

TABLE 24. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + NICKEL ALLOYS (Temperature Dependence) (continued)

DATA SET 148*

T	ρ
1.42	0.037
4.22	0.037
14.25	0.036
20.35	0.037
273.15	1.601

DATA SET 149

T	ρ
1.42	0.152
4.22	0.152
14.25	0.151
20.35	0.153
273.15	1.757

DATA SET 150

T	ρ
1.42	0.897
4.22	0.896
14.25	0.888
20.45	0.890
273.15	2.522

DATA SET 151

T	ρ
1.42	2.549
4.22	2.542
14.25	2.535
20.45	2.334
273.15	4.291

DATA SET 152

T	ρ
6	39.513
11	39.443
18	39.388
28	39.348
41	39.330
49	39.349
62	39.375
71	39.416
78	39.470
91	39.513
99	39.577
110	39.635
119	39.674
128	39.715

DATA SET 152 (cont.)

T	ρ
139	39.759
149	39.808
159	39.845
177	39.884
200	39.929
218	39.955
237	39.972
256	39.982
288	39.977
308	39.974
330	39.965
351	39.939
370	39.909
390	39.879
409	39.851
434	39.821
452	39.798
471	39.766
490	39.736
510	39.704
532	39.676
553	39.655
570	39.631
589	39.612
609	39.594
631	39.584
653	39.575
669	39.571
691	39.580
712	39.617
732	39.660
750	39.702
770	39.742
790	39.784
810	39.817
827	39.857
848	39.906
869	39.957
889	40.017
908	40.075

DATA SET 153

T	ρ
1.83	5.98026
2.13	5.97999
2.72	5.97997
3.34	5.97984
4.23	5.97980
5.25	5.98017
6.50	5.98020
7.76	5.98040
11.16	5.98071
15.22	5.98151
19.36	5.98326
23.45	5.98674
27.05	5.99166
31.92	6.00244
39.10	6.02621
47.38	6.06457
54.62	6.10788
63.00	6.16381
70.06	6.21496
79.55	6.28636
90.06	6.37416
99.46	6.44993

DATA SET 154

T	ρ
1.80	13.8605
1.90	13.8604
2.47	13.8607
3.01	13.8609
3.51	13.8614
3.99	13.8616
4.32	13.8625
5.09	13.8634
5.94	13.8639
7.40	13.8641
9.95	13.8643
12.57	13.8645
15.97	13.8650
19.11	13.8664
20.60	13.8669
24.28	13.8702
27.85	13.8764
31.99	13.8863
38.00	13.9086
42.50	13.9285
45.26	13.9437

DATA SET 154 (cont.)

T	ρ
46.57	13.9512
50.90	13.9763
87.96	14.0237
66.23	14.0857
74.98	14.1558
85.41	14.2444
98.57	14.3650

DATA SET 155

T	ρ
1.17	23.9469
1.68	23.9470
2.00	23.9469
2.43	23.9470
2.81	23.9471
3.22	23.9471
3.59	23.9473
3.91	23.9475
4.20	23.9475
5.04	23.9471
6.89	23.9465
9.13	23.9465
9.92	23.9462
11.12	23.9457
13.76	23.9466
17.19	23.9462
21.23	23.9481
24.50	23.9500
27.99	23.9539
31.63	23.9639
35.65	23.9766
39.23	23.9920
42.60	24.0071
44.33	24.0232
50.23	24.0584
54.95	24.0888
59.68	24.1206
65.19	24.1701
71.91	24.2239
79.82	24.3007
89.88	24.3962
100.55	24.5002

* Not shown in figure.

TABLE 25. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF NICKEL + COPPER ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Cu	Composition (continued), Specifications, and Remarks
1	204	Kondorskii, E.I., Galkina, O.S., and Chernikova, L.A.	1958	A	2.0-70			25.1	Wire specimens 0.1 to 0.2 mm in diameter; heated in a vacuum at 900 C for an hour and then cooled slowly in furnace: ρ_0 = 20.25 $\mu\Omega$ cm.
2	204	Kondorskii, E.I., et al.	1958	A	2.3-71			20	Similar to the above specimen; ρ_0 = 16.22 $\mu\Omega$ cm.
3*	204	Kondorskii, E.I., et al.	1958	A	2.2-72			20	The above specimen reheated to 900 C and quenched in air; ρ_0 = 17.80 $\mu\Omega$ cm.
4*	204	Kondorskii, E.I., et al.	1958	A	1.8-72			15.1	Wire specimen 0.1 to 0.2 mm in diameter; heated in a vacuum at 900 C for an hour and then cooled slowly in furnace: ρ_0 = 12.65 $\mu\Omega$ cm.
5	204	Kondorskii, E.I., et al.	1958	A	2.3-71			15.1	The above specimen reheated to 900 C and quenched in air; ρ_0 = 14.26 $\mu\Omega$ cm.
6*	204	Kondorskii, E.I., et al.	1958	A	1.8-72			9.9	Wire specimen 0.1 to 0.2 mm in diameter; heated in a vacuum at 900 C for an hour and then cooled slowly in furnace; ρ_0 = 9.27 $\mu\Omega$ cm.
7	204	Kondorskii, E.I., et al.	1958	A	1.9-71			9.9	The above specimen reheated to 900 C and quenched in air; ρ_0 = 10.0 $\mu\Omega$ cm.
8	204	Kondorskii, E.I., et al.	1958	A	2.1-71			4.6	Wire specimen 0.1 to 0.2 mm in diameter; heated in a vacuum at 900 C for an hour and then cooled slowly in furnace; ρ_0 = 4.95 $\mu\Omega$ cm.
9	160	Standley, K.J. and Reich, K.H.	1955		293, 473			0.87	Calculated composition (0.8 a/o Cu); supplied by Mond Nickel Co.; Curie temperature 347 C.
10	160	Standley, K.J. and Reich, K.H.	1955		293, 473			4.96	Calculated composition (4.6 a/o Cu); supplied by Mond Nickel Co.; Curie temperature 308 C.
11	160	Standley, K.J. and Reich, K.H.	1955		293-473			10.47	Calculated composition (9.75 a/o Cu); supplied by Mond Nickel Co.; Curie temperature 256 C.
12	160	Standley, K.J. and Reich, K.H.	1955		293-448			15.82	Calculated composition (14.8 a/o Cu); supplied by Mond Nickel Co.; Curie temperature 203 C.
13*	160	Standley, K.J. and Reich, K.H.	1955		293-358			26.2	Calculated composition (24.7 a/o Cu); supplied by Mond Nickel Co.; Curie temperature 105 C.
14	160	Standley, K.J. and Reich, K.H.	1955		293, 348			20	Calculated composition (26.4 a/o Cu); supplied by Mond Nickel Co.; Curie temperature reported as 89 C.
15*	160	Standley, K.J. and Reich, K.H.	1955		293.2			30.1	Calculated composition (28.5 a/o Cu); supplied by Mond Nickel Co.; Curie temperature 69 C.
16	205	Allison, F.E. and Pugh, E.M.	1956	A	64-310		60	40	2 cm wide and 1 mm thick with 4.5 cm in length exposed between copper lugs.
17	205	Allison, F.E. and Pugh, E.M.	1956	A	64-399		70	30	Similar to the above specimen.
18	205	Allison, F.E. and Pugh, E.M.	1956	A	77-302		80	20	Similar to the above specimen.
19	164	Svensson, B.	1936		273-773			41.37	Calculated composition (39.80 a/o Cu).
20	164	Svensson, B.	1936		273-773			29.72	Calculated composition (28.10 a/o Cu).
21*	164	Svensson, B.	1936		273-773			20.81	Calculated composition (19.54 a/o Cu).

* Not shown in figure.

TABLE 25. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF NICKEL + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Cu	Composition (continued), Specifications, and Remarks
22	164	Svensson, B.	1936		273-773			10.32	Calculated composition (9.61 a/o Cu).
23	206	Galkina, O.S. and Chernikova, L.A.	1960		294			39.6	Annealed in vacuum at 900 C for six h and then slowly cooled at the rate of 50 C h^{-1}.
24*	206	Galkina, O.S. and Chernikova, L.A.	1960		294			44.55	Similar to the above specimen.
25*	206	Galkina, O.S. and Chernikova, L.A.	1960		294			49.6	Similar to the above specimen.
26	220	Van Elst, H.C. and Gorter, C.J.	1954	B	14-273		60	40	Polycrystalline; wire specimen 1 mm^2 in cross-section and 20 mm long; supplied by Laboratories of the Philips Lampworks, Eindhaven.
27	207	Farrell, T. and Greig, D.	1968	A	4.2, 273			0.34	Calculated composition (0.31 a/o Cu); 3 mm diameter x 9 cm long; prepared by Metals Research Ltd.; machined; annealed at 850 C for 15 h; reported error ± 7%.
28	207	Farrell, T. and Greig, D.	1968	A	4.2, 273			0.87	Nominal composition (calculated from 0.8 a/o Cu); similar to the above specimen.
29	207	Farrell, T. and Greig, D.	1968	A	4.2, 273			5.28	Nominal composition (calculated from 4.9 a/o Cu); similar to the above specimen.
30	187	Dutta-Roy, S.K. and Subrahmanyam, A.V.	1969	V	79-706		59.99	40.01	Calculated composition (61.87 a/o Ni); spectrographically pure; procured from Johnson Matthey and Co.; 30 x 6 x 0.3 mm^3; annealed for 24 h at 800 C in a vacuum furnace.
31	187	Dutta-Roy, S.K. and Subrahmanyam, A.V.	1969	V	78-718		70.05	29.95	Calculated composition (71.68 a/o Ni); similar to the above specimen.
32*	187	Dutta-Roy, S.K. and Subrahmanyam, A.V.	1969	V	79-726		79.99	20.01	Calculated composition (81.23 a/o Ni); similar to the above specimen.
33	187	Dutta-Roy, S.K. and Subrahmanyam, A.V.	1969	V	82-720		89.93	10.07	Calculated composition (90.62 a/o Ni); similar to the above specimen.
34	208	Kondorskii, E.I., Galkina, O.S., and Chernikova, L.A.	1958	A	2.0-20		74.9	25.1	Wire specimen 0.1 to 0.2 mm in diameter; supplied by Central Scientific Research Institute of Ferrous Metallurgy; cold drawn; annealed in neutral gas at 900 C for 1 to 12 h and cooled slowly.
35	208	Kondorskii, E.I., et al.	1958	A	0-19		80.9	19.1	Similar to the above specimen.
36	208	Kondorskii, E.I., et al.	1958	A	0-20		84.9	15.1	Similar to the above specimen.
37	208	Kondorskii, E.I., et al.	1958	A	0-20		90.1	9.9	Similar to the above specimen.
38	208	Kondorskii, E.I., et al.	1958	A	0-20		95.4	4.6	Similar to the above specimen.
39	171	Crangle, J. and Butcher, P.J.L.	1970	A	11-295		50.02	49.98	Calculated composition (48 a/o Cu); prepared by melting together spectrographically pure Cu and Ni in an argon arc furnace and then annealing the melts in vacuo for three days at above 1300 K; long, thin cylinder specimen accurately machined.

* Not shown in figure.

TABLE 25. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF NICKEL + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Cu	Composition (continued), Specifications, and Remarks
40	143	Schüle, W. and Kehrer, H.P.	1961	V	309-1273		58.09	41.91	Calculated composition (40 a/o Cu); 0.4 mm diameter wire specimen; prepared by melting the components in high frequency furnace under Argon atmosphere; 90% deformed; electrical resistivity measured during heating.
41*	143	Schüle, W. and Kehrer, H.P.	1961	V	308-1273		58.09	41.91	The above specimen measured during cooling.
42*	188	Lecordier, J.C. and Colombani, A.	1968		300-896		53.5	46.5	Calculated composition (55.5 a/o Ni); film specimen prepared by evaporation and deposition at 1500 C.
43*	188	Lecordier, J.C. and Colombani, A.	1968		301-896		59.6	40.4	Calculated composition (61.5 a/o Ni); similar to the above specimen.
44	188	Lecordier, J.C. and Colombani, A.	1968		301-886		73.1	26.9	Calculated composition (74.6 a/o Ni), similar to the above specimen.
45	188	Lecordier, J.C. and Colombani, A.	1968		294-889		84.5	15.5	Calculated composition (85.5 a/o Ni); similar to the above specimen.
46*	189	Sager, G.F.	1930	B	299-1029		60	40	0.2 Mn, and 0.17 Mg; 0.2 cm wire prepared from Mond Nickel by fusing, chill-casting, hot-rolling, and cold-drawing; annealed at 700 C for 12 h.
47	189	Sager, G.F.	1930	B	299-1017		80	20	Similar to the above specimen.
48	209	Greig, D. and Harrison, J.P.	1965	A	2.0-36	C		0.65	Calculated composition (0.6 a/o Cu); cylindrical specimen 4 mm in diameter; supplied by Johnson Matthey and Co.; chill cast from J.M. 890 Ni and J.M. 30 Cu; annealed at 850 C for 12 h; small grains, very fine grain boundaries.
49	209	Greig, D. and Harrison, J.P.	1965	A	2.0-31	D		1.62	Calculated composition (1.5 a/o Cu); similar to the above specimen except long grains running in one direction and very thick (~0.05 mm) grain boundaries.
50	209	Greig, D. and Harrison, J.P.	1965	A	2.0-30	E		4.53	Calculated composition (4.2 a/o Cu); similar to the above specimen except various sizes of grain and various thickness of grain boundaries.
51	209	Greig, D. and Harrison, J.P.	1965	A	2.0-36	F		0.35	Calculated composition (0.32 a/o Cu); similar to the above specimen except mostly small grains, but few long grains running from center.
52	209	Greig, D. and Harrison, J.P.	1965	A	2.0-36	G		5.39	Composition estimated from residual electrical resistivity measurement (5.0 a/o Cu); similar to the above specimen but many grains running from center.
53*	210	Farrell, T. and Greig, D.	1969	A	4.2, 273			0.34	Calculated composition (0.31 a/o Cu); about 3 mm in diameter and 9 cm long; supplied by Metals Research Ltd.; annealed at 1123 K for 15 h.
54	130	Sedström, E.	1919		273, 373			39.1	Calculated composition (62.8 a/o Ni); rolled and drawn to 1 mm in diameter; annealed at near melting point for 30 min.
55	130	Sedström, E.	1919		273, 373			18.4	Calculated composition (82.8 a/o Ni); similar to the above specimen.

* Not shown in figure.

TABLE 25. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF NICKEL + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Composition (weight percent) Cu	Composition (continued), Specifications, and Remarks
56	151	Ahmad, W.M. and Greig, D.	1974		293-873		70.37	29.63	Composition given by authors as 28% Cu; compositions not specified as at. or wt.% but review of other evidence, including comparison of resistivities with those of other investigators is most consistent with conclusion that compositions are at.%; prepared by M.J. Walker from Johnson-Matthey Spec-Pure Ni and Cu; melted in argon arc, ingot rolled and drawn to wire of 0.5 mm diameter and about 120 cm length, cut to 10 cm length, and annealed in vacuum at 1223 K for about 24 h; resistivities accurate to better than 0.1% and temperatures to better than 1%; data extracted from tables.
57	151	Ahmad, W.M. and Greig, D.	1974		293-873		60.11	39.89	Composition given by authors as 38% Cu; similar to the above specimen.
58*	151	Ahmad, W.M. and Greig, D.	1974		293-873		53.03	46.97	Composition given by authors as 45% Cu; similar to the above specimen.
59*	151	Ahmad, W.M. and Greig, D.	1974		293-873		48.02	51.98	Composition given by authors at 50% Cu; similar to the above specimen.
60	158	Yao, Y.D.	1978		77.8-681			4.96	Composition given by author as 4.6 at.% Cu; measured with conventional four-probe technique using a cryostat for 78 to 300 K and a Marshall furnace for 300 to 700 K; data extracted from figure.
61	158	Yao, Y.D.	1978		78.0-700			9.99	Composition given by author as 9.3 at.% Cu; similar to the above specimen.
62	158	Yao, Y.D.	1978		78.2-697			14.98	Composition given by author as 14.0 at.% Cu; similar to the above specimen.
63	158	Yao, Y.D.	1978		78.4-693			20.04	Composition given by author as 18.8 at.% Cu; similar to the above specimen.
64	211	Yarbrough, D.W., Williams, R.K., and Graves, R.S.	1979		300-1000		50	50	Cylindrical specimen approximately 1.0 by 7.6 cm; prepared by arc-casting equal weights of constituent elements, machining, and annealing prior to installation in apparatus; spectrographic analysis showed <0.3 wt.% As, 0.03 Cr, 0.03 wt.% Si, and small amounts of several other metals; analytical results showed C, H, N, and O in the low ppm range; total determinate error ±0.4%; 13 data points smoothed by least squares fit to the equation $\rho = 0.511993 - 0.861508 \times 10^{-4} T + 0.600814 \times 10^{-10} T^3 + 0.214854 \times 10^3 T^{-2}$ (where T is the absolute temperature in Kelvin degrees) with an average deviation of 0.20% and variance of 0.0172; smoothed values extracted from table.
65	212	Greig, D. and Rowlands, J.A.	1974		0-40			0.011	Nominal composition given as 0.01 at.% Cu, but authors state "sample clearly contains an additional impurity"; measured by T. Farrell, but no measurement information reported; data extracted from table.
66	212	Greig, D. and Rowlands, J.A.	1974		0-40			0.043	Nominal composition given as 0.04 at.% Cu; measured by T. Farrell, but no measurement information reported; data extracted from table.
67	212	Greig, D. and Rowlands, J.A.	1974		0-40			0.173	Nominal composition given as 0.16 at.% Cu; measured by J.P. Harrison, but no measurement information reported; data extracted from table.

* Not shown in figure.

TABLE 2 MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF NICKEL + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Cu	Composition (continued), Specifications, and Remarks
68	212	Greig, D. and Rowlands, J.A.	1974		0–40			0.336	Nominal composition given as 0.3 at.% Cu; measured by T. Farrell, but no measurement information reported; appears to be the same specimen as Ni + Cu data set 27; data extracted from table.
69	212	Greig, D. and Rowlands, J.A.	1974		0–40			0.87	Nominal composition given as 0.8 at.% Cu; measured by J.P. Harrison, but no measurement information reported; appears to be the same specimen as Ni + Cu data set 28; data extracted from table.
70	212	Greig, D. and Rowlands, J.A.	1974		0–40			1.73	Nominal composition given as 1.6 at.% Cu; measured by J.P. Harrison, but no measurement information reported; data extracted from table.
71	212	Greig, D. and Rowlands, J.A.	1974		0–40			5.28	Nominal composition given as 4.9 at.% Cu; measured by J.P. Harrison, but no measurement information reported; appears to be the same specimen as Ni + Cu set 29; data extracted from table.

TABLE 26. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF NICKEL + COPPER ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

DATA SET 1

T	ρ
2.0	19.94
2.4	19.94*
3.2	19.94*
3.9	19.97*
4.7	19.97*
5.3	20.00
6.1	20.00*
6.8	20.00*
7.9	20.12*
7.7	20.23
8.8	20.33*
10.0	20.37*
10.8	20.37
12.1	20.38*
13.9	20.39
16.1	20.39*
19.4	20.39*
20.6	20.42*
23.6	20.47*
26.0	20.52
27.5	20.52*
29.1	20.56*
29.4	20.56*
34.0	20.58
37.2	20.58*
38.9	20.61
40.9	20.68*
42.5	20.70*
44.5	20.79*
46.3	20.84
48.4	20.90*
49.7	20.90*
52.4	21.03
55.4	21.14*
58.2	21.25*
60.4	21.31*
62.7	21.33
64.6	21.47*
67.6	21.61*
69.9	21.75

DATA SET 2

T	ρ
2.3	16.32
2.9	16.32*

DATA SET 2 (cont.)

T	ρ
3.4	16.32*
3.8	16.32*
4.2	16.33*
4.7	16.33*
5.8	16.35*
7.1	16.40*
7.9	16.43*
9.5	16.43
11.5	16.43*
13.8	16.46
15.5	16.46*
17.2	16.50*
18.9	16.50*
21.0	16.51*
23.0	16.51
25.0	16.51*
26.4	16.51*
26.6	16.51*
27.9	16.54*
31.3	16.54*
33.2	16.54
35.1	16.57*
37.1	16.58*
39.1	16.62*
42.0	16.68
43.7	16.71*
47.0	16.76*
48.6	16.85*
53.0	16.97
55.1	17.02*
56.6	17.03*
58.9	17.10*
62.6	17.19*
63.2	17.22*
64.6	17.32*
66.0	17.33*
68.0	17.40*
71.0	17.47

DATA SET 3*

T	ρ
2.2	17.71
2.8	17.71
3.4	17.71
3.7	17.71

DATA SET 3 (cont.)*

T	ρ
4.1	17.71
4.6	17.71
5.3	17.71
6.2	17.71
7.3	17.79
8.1	17.87
10.1	17.87
11.9	17.87
13.9	17.89
16.0	17.89
18.0	17.90
21.0	17.93
22.7	17.93
25.4	17.95
27.3	17.98
29.4	17.98
31.4	17.98
34.0	17.98
36.4	18.00
39.2	18.00
41.8	18.04
44.3	18.06
47.2	18.11
50.4	18.32
52.9	18.35
54.5	18.41
57.1	18.51
60.6	18.60
62.4	18.68
65.9	18.73
68.0	18.80
72.0	19.02

DATA SET 4*

T	ρ
1.8	13.69
2.3	13.69
2.7	13.69
3.3	13.74
3.8	13.77
4.0	13.90
4.1	14.03
4.5	14.14
4.9	14.17
5.4	14.25

DATA SET 4 (cont.)*

T	ρ
6.1	14.25
6.8	14.30
8.2	14.34
10.1	14.36
11.8	14.36
13.9	14.36
16.0	14.38
18.1	14.38
21.0	14.43
22.3	14.43
24.0	14.43
26.4	14.43
29.5	14.48
31.6	14.48
34.0	14.52
37.3	14.52
39.0	14.54
41.3	14.58
42.6	14.59
44.3	14.61
47.9	14.70
50.3	14.74
53.0	14.84
56.5	14.90
58.1	14.99
60.5	15.05
64.2	15.08
66.6	15.16
68.2	15.20
69.9	15.29
72.1	15.31

DATA SET 5

T	ρ
2.3	12.68
2.8	12.68*
3.3	12.68*
3.7	12.[illegible]*
4.4	12.68*
7.9	12.70
9.9	12.74*
11.1	12.74*
13.5	12.77
15.6	12.77*
17.5	12.80*

DATA SET 5 (cont.)

T	ρ
19.0	12.80*
20.9	12.82*
22.4	12.82*
23.7	12.82
25.8	12.85*
27.9	12.86*
30.7	12.90*
33.0	12.90
34.7	12.90*
37.4	12.90*
38.8	12.90*
41.2	12.94
43.4	12.94*
45.1	12.98*
46.7	13.01*
49.1	13.01*
50.8	13.09*
52.8	13.06
56.1	13.10*
57.4	13.15*
62.5	13.31
65.3	13.35*
67.2	13.45*
69.0	13.53*
70.9	13.61

DATA SET 6*

T	ρ
1.8	9.74
2.3	9.74
2.8	9.74
3.2	9.74
3.7	9.74
4.0	9.74
4.6	9.78
5.1	9.91
5.9	9.96
7.3	9.96
8.1	10.02
10.2	10.01
12.0	10.01
14.0	10.02
16.3	10.07
18.0	10.07
20.8	10.07

DATA SET 6 (cont.)*

T	ρ
23.5	10.09
25.6	10.12
27.7	10.12
29.7	10.12
32.0	10.15
34.3	10.15
35.7	10.19
37.6	10.21
39.0	10.21
42.2	10.27
44.5	10.30
46.6	10.32
49.0	10.37
50.5	10.40
53.0	10.43
55.6	10.45
57.6	10.45
59.2	10.60
60.8	10.55
62.8	10.57
65.1	10.59
67.4	10.62
69.8	10.70
72.1	10.77

DATA SET 7

T	ρ
1.9	9.28
2.4	9.28*
3.1	9.28*
3.4	9.29*
3.7	9.29*
4.1	9.29*
4.6	9.29*
5.3	9.29
5.9	9.29*
8.4	9.29*
9.4	9.29*
11.8	9.32
15.3	9.32*
17.1	9.35*
18.9	9.35*
21.1	9.39*
22.4	9.39*
24.3	9.42*

* Not shown in figure.

TABLE 26. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF NICKEL + COPPER ALLOYS (Temperature Dependence) (continued)

DATA SET 7 (cont.)

T	ρ
27.9	9.41
31.2	9.44
32.7	9.46*
35.2	9.46*
38.8	9.48*
40.8	9.55
42.7	9.55*
46.6	9.58*
49.1	9.58
50.7	9.62*
52.6	9.69*
54.7	9.71*
58.9	9.74
60.6	9.86*
62.4	9.88
64.4	9.92*
66.3	9.95
69.6	9.99*
70.8	10.08

DATA SET 8

T	ρ
2.1	4.95
2.6	5.00*
3.3	5.00
3.9	4.99*
4.4	5.00*
4.8	4.99*
5.2	5.00
5.9	4.99*
6.8	5.00*
7.6	5.00*
9.7	5.00
12.0	5.01
12.9	5.04*
15.4	5.04
18.8	5.04*
21.1	5.04
24.1	5.07*
26.1	5.07
27.8	5.07*
31.1	5.08*
33.0	5.08*
34.1	5.05*
36.0	5.08
37.4	5.04*
39.0	5.04

DATA SET 8 (cont.)

T	ρ
42.4	5.08
46.0	5.15
46.9	5.19*
50.2	5.23
53.1	5.31*
55.8	5.37*
57.8	5.40
59.8	5.48*
62.1	5.53
65.0	5.58*
67.0	5.60*
68.9	5.67*
70.9	5.75

DATA SET 9

T	ρ
293.2	7.9
473.2	16.0

DATA SET 10

T	ρ
293.2	12.6
473.2	22.5

DATA SET 11

T	ρ
293.2	19.8
423.2	28.9
473.2	32.5

DATA SET 12

T	ρ
293.2	26.0
373.2	32.4
448.2	38.3

DATA SET 13*

T	ρ
293.2	38.2
358.2	44.1

DATA SET 14

T	ρ
293.2	39.8
348.2	44.7

DATA SET 15*

T	ρ
293.2	41.5

DATA SET 16

T	ρ
64	34.12
77	35.34
112	37.76
169	42.00
210	44.57
231	45.33
300	46.91
310	47.29

DATA SET 17

T	ρ
64	24.89
77	25.31
112	27.55
169	31.40
206	34.41
230	36.22
269	39.55
291	41.48*
295	41.89
304	42.55
316	43.71*
327	44.29
341	44.90*
354	45.23*
364	45.77
399	46.48

DATA SET 18

T	ρ
77	16.22
112	17.55
169	20.26
231	23.82
302	29.27

DATA SET 19

T	ρ
273.2	51.40
323.2	51.80
373.2	52.08
423.2	52.27
473.2	52.47

DATA SET 19 (cont.)

T	ρ
523.2	52.69
573.2	52.81
623.2	53.02
673.2	53.49
723.2	54.01
773.2	54.57

DATA SET 20

T	ρ
273.2	40.22
323.2	44.90
373.2	47.73
423.2	48.70
473.2	49.34
523.2	49.97
573.2	50.60
623.2	51.23
673.2	51.86
723.2	52.49
773.2	53.13

DATA SET 21*

T	ρ
273.2	28.96
323.2	33.02
373.2	37.80
423.2	42.75
473.2	44.44
523.2	45.54
573.2	46.39
623.2	47.27
673.2	48.17
723.2	49.05
773.2	49.92

DATA SET 22

T	ρ
273.2	16.96
323.2	19.98
373.2	23.22
423.2	26.96
473.2	31.38
523.2	36.79
573.2	38.74
623.2	40.10
673.2	41.34
723.2	42.52
773.2	43.68

DATA SET 23

T	ρ
293.6	34.39

DATA SET 24*

T	ρ
293.6	39.34

DATA SET 25*

T	ρ
293.6	44.48

DATA SET 26

T	ρ
14	29.40
20	29.62
64	31.59
77	32.30
273	44.46

DATA SET 27

T	ρ
4.2	0.247
273.2	6.67

DATA SET 28

T	ρ
4.2	0.627
273.2	7.26

DATA SET 29

T	ρ
4.2	3.70
273.2	11.18

DATA SET 30

T	ρ
79	48.4
111	51.6
169	57.6
210	61.2
309	64.9
335	64.7
387	65.0
434	64.6
511	64.9
563	66.3
636	67.0
706	67.1

DATA SET 31

T	ρ
78	31.4
112	34.3
168	39.4
207	43.2
232	45.5
270	49.5
292	52.0
305	53.4
314	54.4
335	56.1
354	56.9
378	57.4
399	58.6
456	58.7
536	59.4
658	60.5
718	61.0*

DATA SET 32*

T	ρ
79	18.8
112	20.3
169	23.6
231	27.7
303	34.0
332	38.0
370	41.4
399	44.9
442	48.3
498	49.7
566	50.9
602	52.0
639	52.2
676	53.6
726	54.1

DATA SET 33

T	ρ
82	11.2
165	14.5
211	17.1
261	19.9
295	22.8
303	23.6
362	28.0
414	32.7
428	33.1

* Not shown in figure.

TABLE 26. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF NICKEL + COPPER ALLOYS (Temperature Dependence) (continued)

DATA SET 33 (cont.)

T	ρ
473	38.4
510	43.1
553	46.4
582	48.0
636	49.6
720	50.9

DATA SET 34

T	ρ
2.03	19.09
2.43	19.15
2.73	19.15
3.08	19.15
3.34	19.15
3.65	19.15
3.96	19.19*
4.30	19.24
13.24	19.32*
14.12	19.36
15.90	19.36*
17.85	19.36*
19.10	19.36
19.92	19.36*
20.40	19.36

DATA SET 35

T	ρ
0.00	13.70*
1.93	13.70
2.26	13.77*
2.47	13.77*
2.73	13.77
3.02	13.77
3.34	13.83*
3.62	13.99*
3.84	14.17*
4.14	14.43*
13.90	14.83*
14.78	14.86
15.91	14.88
16.91	14.88*
17.55	14.86*
19.42	14.88

DATA SET 36

T	ρ
0.00	11.44*

DATA SET 36 (cont.)

T	ρ
2.05	11.48
2.41	11.49*
2.83	11.52*
3.26	11.52*
3.56	11.52*
3.78	11.52*
4.14	11.55
4.44	11.64*
13.90	11.77
14.75	11.79*
15.78	11.79*
16.95	11.79
17.87	11.79*
19.31	11.79*
19.91	11.79

DATA SET 37

T	ρ
0.00	8.47*
2.36	8.46
3.08	8.46
3.78	8.46
4.32	8.46
14.69	8.50
16.44	8.55*
19.78	8.55*
20.44	8.55

DATA SET 38

T	ρ
0.00	4.57*
1.78	4.63
2.25	4.63
2.61	4.60*
3.06	4.61*
3.41	4.61*
3.64	4.61*
3.92	4.61*
4.34	4.65
13.82	4.65
14.84	4.65*
15.90	4.65*
17.75	4.65
19.46	4.65*
20.06	4.65

DATA SET 39

T	ρ
11	41.2
19	41.9
29	42.6
37	43.2
44	43.9
63	45.2
76	46.0
87	46.6
94	47.0
100	47.2
110	47.5
121	47.8
131	48.1
151	48.4
176	48.9
197	49.2
223	49.4
255	49.7
295	49.9

DATA SET 40

T	ρ
309.2	50.75
330.2	50.61
357.2	50.54
391.2	50.35
421.2	50.01*
473.2	49.73*
620.2	49.03*
673.2	48.78*
698.2	48.72
743.2	48.80
788.2	49.01
872.2	49.58
1074.2	51.30
1170.2	52.17
1220.2	52.71*
1273.2	53.38

DATA SET 41*

T	ρ
308.2	47.16
472.2	47.48
570.2	47.75
672.2	48.21
749.2	48.70
788.2	49.01

DATA SET 41 (cont.)*

T	ρ
872.2	49.58
1074.2	51.30
1170.2	52.17
1220.2	52.71
1273.2	53.38

DATA SET 42*

T	ρ
300	51.2
395	51.3
472	51.3
538	51.3
607	51.3
678	51.4
747	51.6
819	52.1
896	52.6

DATA SET 43*

T	ρ
301	48.9
356	49.4
372	49.4
416	49.7
464	49.8
545	50.0
608	50.3
677	50.6
744	50.9
818	51.4
896	52.0

DATA SET 44

T	ρ
301	33.3
404	39.6
456	41.9
535	44.6
604	46.2
681	47.3
753	48.4
814	49.3
886	50.2

DATA SET 45

T	ρ
294	22.6

DATA SET 45 (cont.)

T	ρ
380	27.9
439	31.7
531	38.0
602	41.7
668	43.8
746	45.7
782	46.4
816	47.0
889	48.2

DATA SET 46*

T	ρ
290	53.2
406	53.8
477	54.0
659	54.9
730	55.2
853	56.2
915	56.8
963	57.1
1029	58.1

DATA SET 47

T	ρ
290	27.8
349	32.7
364	34.5
399	36.8
404	37.5
437	40.3
457	41.7
504	42.9
544	44.1
604	45.0
669	46.1
724	47.2
819	49.0
941	50.8
1017	52.1

DATA SET 48

T	ρ
2.0	0.626
4.16	0.627
6.44	0.628
8.22	0.629
10.3	0.631

DATA SET 48 (cont.)

T	ρ
12.2	0.632
14.4	0.636
14.7	0.638*
16.3	0.640*
17.8	0.643
19.5	0.649*
20.5	0.650
22.7	0.657*
23.3	0.658
24.7	0.664*
26.1	0.668*
30.3	0.685
32.7	0.700*
35.6	0.713

DATA SET 49

T	ρ
2.0	1.265
3.42	1.266
4.73	1.267
5.29	1.268*
7.64	1.271
10.3	1.274
12.3	1.278*
15.0	1.283
16.3	1.286*
18.8	1.293*
20.8	1.300
22.8	1.306*
25.7	1.320
30.8	1.346

DATA SET 50

T	ρ
2.0	3.705
8.59	3.714
10.8	3.719
12.4	3.725*
18.7	3.742
22.5	3.751
24.7	3.769*
30.3	3.790

DATA SET 51

T	ρ
2.0	0.199
6.44	0.200

* Not shown in figure.

TABLE 26. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF NICKEL + COPPER ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 51 (cont.)	
8.21	0.201
10.0	0.201
12.1	0.204*
14.3	0.206*
14.6	0.207
16.4	0.209*
18.2	0.212
20.2	0.216*
22.5	0.222
25.9	0.231*
29.9	0.244
36.0	0.269
DATA SET 52	
2.00	3.808
6.28	3.810
8.61	3.814
10.2	3.816
11.9	3.816*
14.5	3.821
16.3	3.823*
18.6	3.828
20.3	3.836*
22.3	3.843
23.8	3.843*
27.7	3.858
30.3	3.874*
32.6	3.866*
35.5	3.905
DATA SET 53*	
4.2	0.247
273.2	6.670
DATA SET 54	
273.2	58.8
373.2	66.7
DATA SET 55	
273.2	37.0
373.2	50.0

T	ρ
DATA SET 56	
293	42.41
333	44.27*
373	45.03
433	45.74
473	46.10
533	46.64
573	46.80
673	47.54*
773	48.53*
873	49.67*
DATA SET 57	
293	47.66
333	48.00
373	48.22
433	48.43
473	48.55
533	48.72
573	48.81
673	49.08*
773	49.54*
873	50.37*
DATA SET 58*	
293	49.89
333	49.78
373	49.67
433	49.47
473	49.33
533	49.17
573	49.06
673	48.88
773	49.00
873	49.55
DATA SET 59*	
293	49.99
333	49.76
373	49.53
433	49.19
473	48.98
533	48.71
573	48.56
673	48.25
773	48.39
873	48.85

T	ρ
DATA SET 60	
77.8	4.91
96.7	5.20
110	5.67
138	6.52
148	6.71*
167	7.46
184	7.93
201	8.69
216	9.35*
224	9.63*
233	10.10
248	10.86*
262	11.71*
277	12.18
294	12.94*
301	13.31*
324	14.54
328	14.54*
341	15.68*
375	17.85
404	19.55*
431	21.54*
451	23.05
476	24.94*
497	26.64
514	27.97*
529	29.19
544	30.71*
552	31.56*
565	32.98*
573	33.73
575	33.92*
577	34.21*
581	34.59*
586	34.77*
590	34.96
594	35.15*
602	35.63*
615	36.19*
638	37.14
662	38.17*
681	39.02
DATA SET 61	
78.0	8.42
106	9.17
141	10.40
167	11.44

T	ρ
DATA SET 61 (cont.)	
199	12.95*
220	13.70
245	15.12
260	15.88
277	16.92*
292	18.05*
306	18.71
330	20.22*
342	21.26
364	22.78*
385	24.00*
402	25.42
414	26.46*
435	28.17
459	30.34*
478	31.76*
494	33.08
499	34.03*
503	34.22*
507	34.60*
507	34.78*
511	34.97
513	35.16*
518	35.54*
518	35.83*
522	36.01*
526	36.39*
528	36.58*
530	36.77*
533	37.05*
537	37.34*
541	37.53*
545	37.81*
549	38.09*
552	38.28
566	38.85*
573	39.13*
585	39.51*
606	40.17*
625	41.02*
647	41.87
662	42.34*
683	43.10*
700	43.66

T	ρ
DATA SET 62	
78.2	12.02
112	13.15
158	15.04
184	16.08*
205	17.30
226	18.63*
249	20.04*
270	21.46
304	23.83*
313	24.58
329	25.91*
351	27.42
370	28.93*
382	30.44*
408	32.15
424	33.56*
433	34.51*
445	35.65*
456	36.78
464	37.44*
467	38.10*
471	38.29*
471	38.48*
475	38.67*
477	38.96*
481	39.14*
484	39.52*
488	39.71*
492	39.90
492	40.00*
496	40.18*
500	40.37*
502	40.47*
507	40.66*
515	41.03*
532	41.60*
551	42.36
575	43.11*
600	43.77
619	44.34*
642	45.00*
663	45.75
682	46.32*
697	46.69

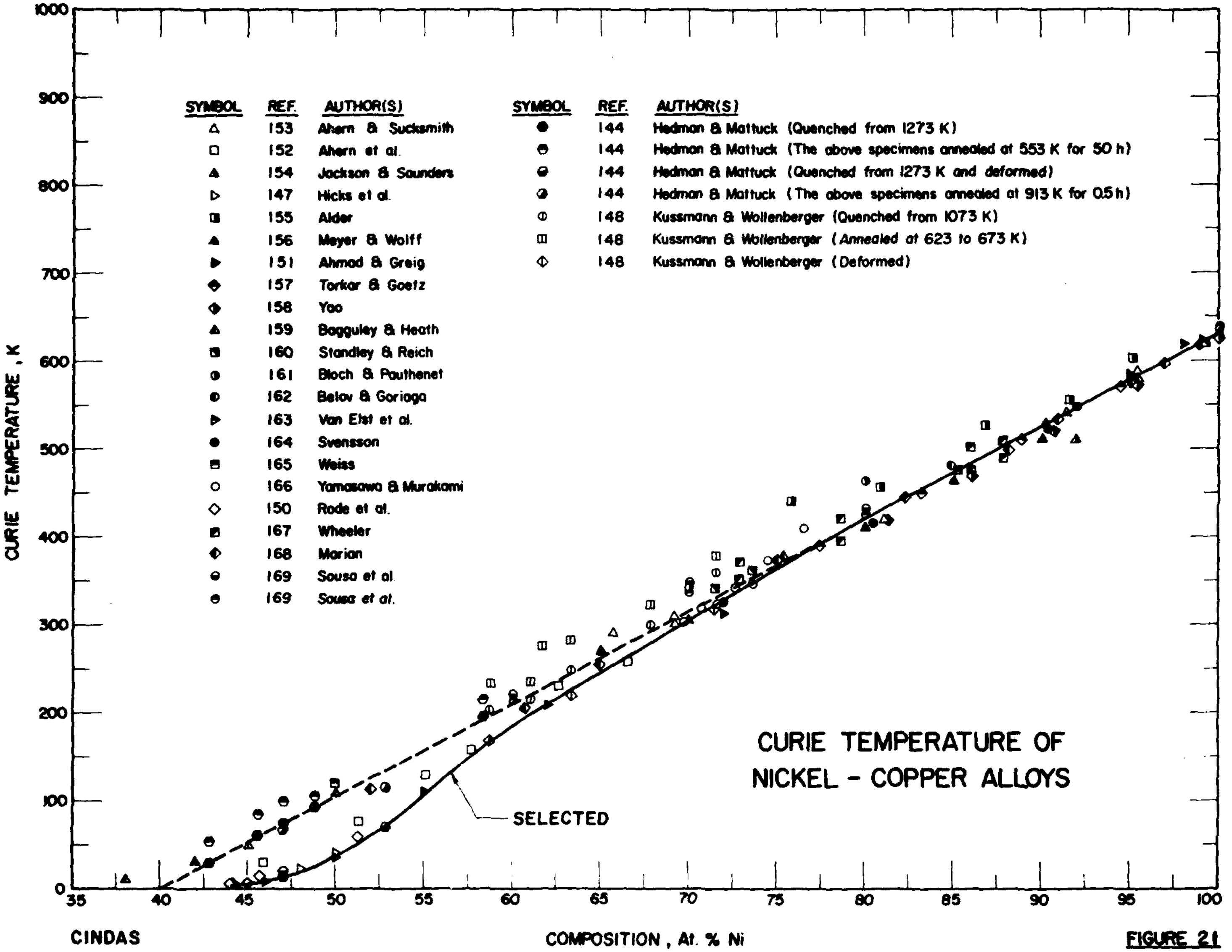
T	ρ
DATA SET 63	
78.4	17.23
101	18.07
120	19.02
130	19.49*
143	19.87*
166	21.29
188	22.70*
219	24.59*
236	26.01
274	29.23*
297	31.40
312	32.54*
325	33.67*
337	35.00
350	36.04*
369	37.93*
380	38.68
396	40.20*
407	41.43*
409	41.90*
416	42.85*
418	43.03*
420	43.32
422	43.51*
428	44.08*
434	44.45*
437	44.83*
443	45.02*
451	45.40
460	45.78*
468	46.15*
475	46.34*
487	46.72*
502	47.29
521	47.95*
534	48.42*
561	49.17
581	49.83*
608	50.40*
636	51.44
661	52.00*
684	52.60*
693	52.85

* Not shown in figure.

TABLE 26. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF NICKEL + COPPER ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 64	
300	49.0
400	48.3
500	47.7*
600	47.4
700	47.3*
800	47.4
900	47.9
1000	48.6
DATA SET 65	
0	0.169*
10.0	0.1701
20.0	0.1792
30.0	0.2003
40.0	0.2465
DATA SET 66	
0	0.044*
10.0	0.0463*
20.0	0.0555*
30.0	0.0760*
40.0	0.1178
DATA SET 67	
0	0.209*
10.0	0.213
20.0	0.226
30.0	0.257
40.0	0.310
DATA SET 68	
0	0.247*
10.0	0.2508
20.0	0.2652
30.0	0.2974
40.0	0.358
DATA SET 69	
0	0.627*
10.0	0.632
20.0	0.651
30.0	0.689
40.0	0.752
DATA SET 70	
0	1.261*
10.0	1.270
20.0	1.295
30.0	1.339
40.0	1.411
DATA SET 71	
0	3.701*
10.0	3.712
20.0	3.739
30.0	3.788
40.0	3.868

* Not shown in figure.



CINDAS

FIGURE 21

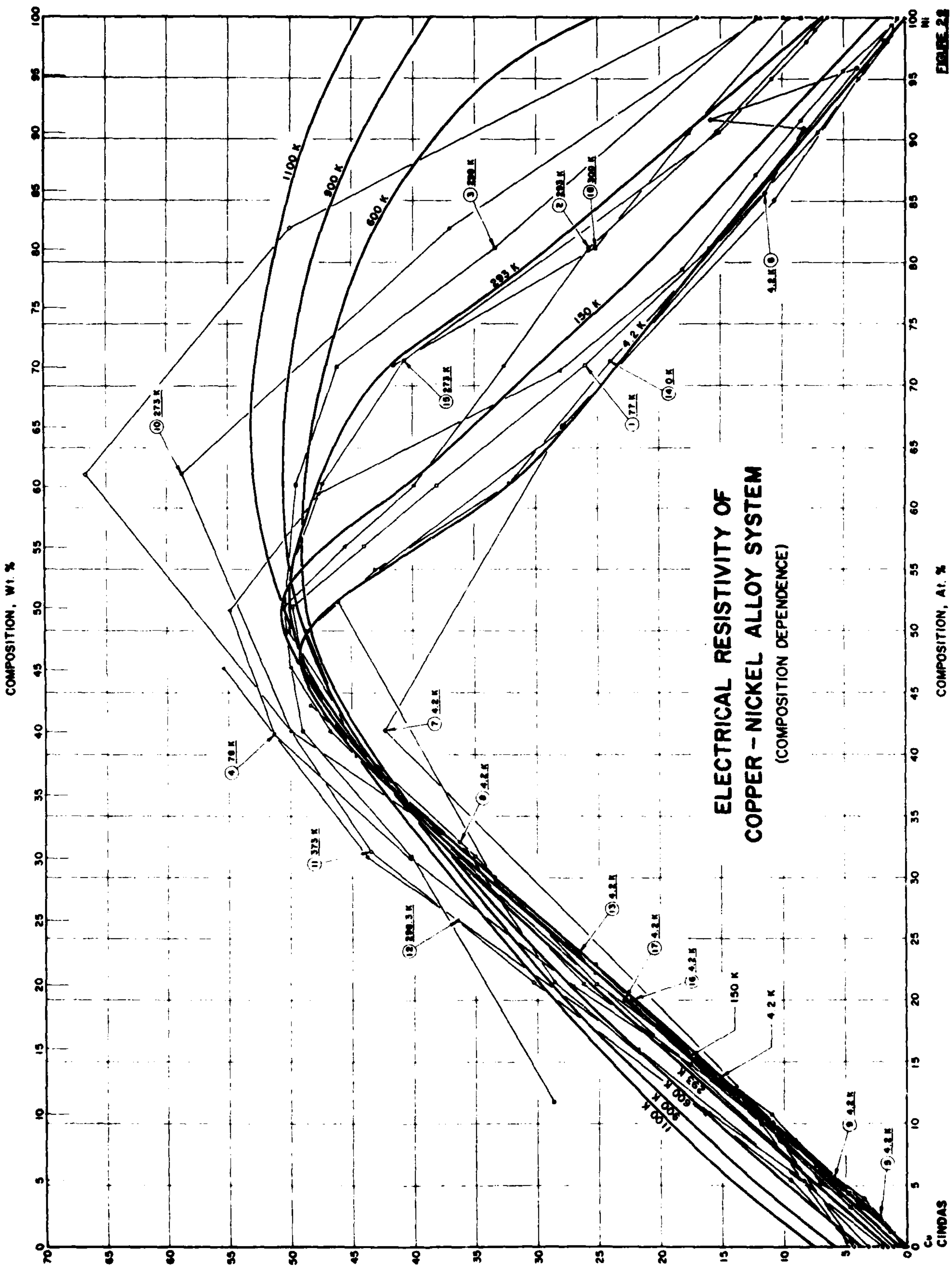

ELECTRICAL RESISTIVITY OF
COPPER-NICKEL ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION, Wt. %
COMPOSITION, At. %
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
1100 K
900 K
600 K
293 K
150 K
4.2 K
Cu
Ni
CINDAS

TABLE 27. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER-NICKEL ALLOY SYSTEM (Composition Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Ni)	Composition (weight percent), Specifications, and Remarks
1	213	Lihl, F. and Wildhack, H.	1971		77	0-100	Specimens prepared from 99.99 pure metals; annealed at 593 to 853 K for 1 h.
2	213	Lihl, F. and Wildhack, H.	1971		293	0-100	The above specimens.
3	55	Smith, A.W.	1925	B	298.2	11-100	Specimens 0.3 cm^2 in cross-section and 5 to 6 cm long; prepared from Baker's analyzed 99.97^+ pure copper and International Nickel Co. of America 99.75 to 99.85 pure nickel.
4	214	Aoyama, S. and Ito, T.	1940	V	78	0-99	Specimens prepared from 99.4 pure electrolytic nickel and 99.9^+ pure electrolytic copper by fusing.
5	215	Erdmann, J.C. and Jahoda, J.A.	1968	A	4.2	2.5-99	Three single crystals 6.0 to 7.5 mm in diameter and 12 cm long; supplied by Materials Research Corp.; prepared by electron beam float zoning technique.
6	215	Erdmann, J.C. and Jahoda, J.A.	1968	A	4.2	10-96	Polycrystalline specimens 5.0 mm in diameter and 10 cm long; supplied by International Nickel Co., Inc.; vacuum-cast ingots hammer forged, hot-rolled to 18 mm in diameter and rough turned, swaged to 10 mm thick and machined to size; annealed in argon at 1203 K for 24 h, cooled slowly.
7	216	Erdmann, J.C. and Johoda, J.A.	1964	A	4.2	2.1-98	Polycrystalline specimens 1.35 to 1.45 mm in diameter and 125 mm long; grain size 50 to 250 μ; supplied by International Nickel Co.; vacuum-cast ingots hammer forged, hot-rolled to 18.5 mm in diameter, rough turned, cold-rolled to 6 mm thick and drawn to ~1.5 mm in diameter; annealed at 1273 K for 24 h.
8	178	Legvold, S., Peterson, D.T., Burgardt, P., Hofer, R.J., Lundell, B., and Vyrostek, T.A.	1974	A	4.2	0.3-44	Specimens 1 mm in diameter and 5 in. long; prepared from American Smelting and Refining Co.; 99.999 pure copper and nickel by melting; swaged and drawn; annealed at 1073 K for 3 days and quenched in ice water.
9	177	Eagen, C.F. and Legvold, S.	1972	A	4.2	0-23	Specimens prepared from American Smelting and Refining Co. 99.999^+ pure copper and 99.999 pure nickel; metals electron-beam melted separately under high vacuum, then arc-melted together in a graphite crucible, swaged and drawn to 0.014 in. thick, cut to 1 in. long and electropolished; annealed in vacuum at 1273 K for 3 days and quenched in ice water.
10	130	Sedström, E.	1919		273.2	0-100	Wire specimens 1 mm in diameter; rolled and drawn; annealed at near melting point for 30 min.
11	130	Sedström, E.	1919		373.2	0-100	The above specimens.
12	142	Köster, W. and Schüle, W.	1957		298.2	0-45	Specimens containing 0, 15, 20, 25, 30, and 45% Ni deformed 70% into ribbons 1 mm thick; heated to 900 °C for 30 minutes and furnace cooled.
13	217	Gartner, H., Zrudsky, D.R., and Legvold, S.	1970		4.2	6.23-23.90	Prepared from high purity Cu and 99.999 pure Ni from American Smelting and Refining Co. by individually electron-beam melting the constituents in an ultra-high vacuum to remove accluded gases, arc melting the alloys several times on a spectrographically pure graphite hearth for homogeneity, sawing with a spark cutter, etching in HNO_3, swaging inside Al jackets after which alloys were removed, carefully cleaned annealed for 72 h at 1273 K, quenched rapidly in ice water, spark cut and lightly polished to a nominal 0.8 x 0.8 mm^2 cross-section, and electropolished to remove damaged surface materials; chemical analysis showed control of objectionable transition metal impurities and metallographs indicated absence of second phase formation; uncertainties in the resistivities of ±0.07, ±0.13 and ±0.26 $\mu\Omega$cm for the 6.23, 11.85, and 23.90 at.% Ni specimens respectively; data extracted from table.

TABLE 27. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER-NICKEL ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Composition Range (At.% of Ni)	Composition (weight percent), Specifications, and Remarks
14	151	Ahmad, H.M. and Greig, D.	1974		0	0-100	Compositions were not specified as at. or wt.% but comparison of resistivities with those of other investigators is most consistent with conclusion that compositions are at.%; prepared by M.J. Walker from Johnson-Matthey Spec-Pure Ni and Cu, copper-rich specimens pre-melted in argon arc followed by homogenization melt in quartz tubes, nickel-rich alloys melted in argon arc only, ingots rolled and drawn to wires of 0.5 mm diameter and about 120 cm length, cut to 10 cm length, and annealed in vacuum at 1223 K for about 24 h; resistivities accurate to better than 0.1% and temperatures known to better than 1%; data extracted from tables.
15	151	Ahmad, H.M. and Greig, D.	1974		273	0-100	The above specimens.
16	218	Linz, R.J., Bowley, A.C., Klaffky, R.W., and Damon, D.H.	1975		4	4-20	Prepared from 99.999% pure Cu and 99.99+% pure Ni, rods of 4 at.% Ni alloy swaged from 0.5 to 0.125 in. diameter and rods of other alloys swaged from 0.25 to 0.125 in. diameter at room temperature; measured in heavily deformed, cold-worked state; 1% absolute error in resistivity with precision typically within 0.1%; data obtained from 1 to 4 K was constant within measurement precision; data extracted from table.
17	218	Linz, R.J., Bowley, A.C., Klaffky, R.W., and Damon, D.H.	1975		4	4-20	The above specimens measured after annealing for 72 h within 20 K of the melting temperature i.e. 1348 K, 1353 K, and 1383 K for the 4, 10, and 20 at.% Ni specimens respectively; cooled slowly after anneal; data extracted from table.
18	219	Kaul, S.N.	1975		300	71.68-100	Spectrographically pure alloys from Johnson Matthey in the form of rectangular textured plates (25 x 5 x 0.3 mm^3) with their length along the rolling direction were the same alloys used in earlier work by Dutta-Roy and Subrahmanyam [Ni + Cu data sets 31-33]; pure Ni samples in order of decreasing resistivity were from E' Merch (nominal purity 99.9%), International Nickel Ltd. (99.99% pure), and Johnson Matthey and were of the same form as the alloys; annealed for 24 h at 1123 K in vacuum of 10^{-6} torr; data extracted from data table.

TABLE 28. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER-NICKEL ALLOY SYSTEM (Composition Dependence)

[Composition, C, a/o Ni; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

DATA SET 1 (T = 77 K)

C	ρ
0.0	0.22
3.2	3.1
8.6	9.1
10.7	11.0
21.3	25.2
31.7	35.0
41.9	46.1
47.0	49.0
52.0	49.8
56.9	44.0
61.9	38.1
71.6	26.0
81.2	15.9
90.7	8.1
100	0.65

DATA SET 2 (T = 293 K)

C	ρ
0.0	1.1
3.2	4.6
8.6	10.3
10.7	12.1
21.3	26.3
31.7	36.3
41.9	46.8
47.0	50.0
52.0	50.5
56.9	45.5
61.9	39.9
71.6	32.6
81.2	25.7
90.7	15.3
100	6.8

DATA SET 3 (T = 298.2 K)

C	ρ
11.7	28.7
31.7	40.3
41.9	49.0
52.0	50.5
61.9	49.5
71.6	46.1
81.2	33.3
100.0	12.1

DATA SET 4 (T = 78 K)

C	ρ
0.00	0.231
1.11	1.039
3.96	2.43
10.2	11.9
14.8	17.6
21.1	27.1
31.6	40.3
41.7	51.4
51.7	54.9
61.2	47.7
71.2	28.0
79.5	18.1
87.1	12.2
91.6	8.50
95.7	5.00
99.4	0.920

DATA SET 5 (T = 4.2 K)

C	ρ
2.47	2.17
4.37	4.95
99.40	0.907*

DATA SET 6 (T = 4.2 K)

C	ρ
9.99	11.22
29.58	33.38
52.47	46.10
66.65	27.62
85.70	11.14
90.91	8.24
91.67	15.88
95.92	3.91

DATA SET 7 (T = 4.2 K)

C	ρ
2.12	2.17
5.11	7.04
10.0	10.34
42	42.3
66.65	27.8
85.1	10.64
98.1	1.65

DATA SET 8 (T = 4.2 K)

C	ρ
0.3	0.5
1.2	1.3
5.3	6.0
5.9	6.7
6.6	7.3
11.6	13.1
12.2	13.6
22.2	25.3
24.1	27.0
32.9	36.3
44.0	48.4

DATA SET 9 (T = 4.2 K)

C	ρ
0.00	0.10
5.5	5.98
12.8	14.0
22.9	25.3

DATA SET 10 (T = 273.2 K)

C	ρ
0.0	3.12
5.4	8.40
10.8	16.1
21.4	28.6
32.1	35.7
41.9	50.0
62.8	58.8
82.8	37.0
100.0	11.8

DATA SET 11 (T = 373.2 K)

C	ρ
0.0	4.39
5.4	9.43
10.8	16.4
21.4	30.3
32.1	43.5
41.9	50.0
62.8	66.7
82.8	50.0
100	16.9

DATA SET 12 (T = 298.3 K)

C	ρ
0.0	2.0
16.0	21.8
26.5	36.5
31.7	43.8
47.0	55.4

DATA SET 13 (T = 4.2 K)

C	ρ
6.23	6.947
11.65	13.112
23.90	26.592

DATA SET 14 (T = 0 K)

C	ρ
0	0.0062
30	33.41
40	44.60
50	48.66
55	43.10
62	32.12
72	23.91
90.6	7.055
95	3.750
98	1.428
99	0.8627
100	0.0419

DATA SET 15 (T = 273 K)

C	ρ
0	1.593
30	34.89
40	43.87
50	50.08
55	49.92
62	47.39
72	40.72
90.6	15.123
95	10.84
98	8.064
99	7.297
100	6.313

DATA SET 16 (T = 4 K)

C	ρ
4	4.540
10	11.263
20	22.350

DATA SET 17 (T = 4 K)

C	ρ
4	4.920
10	11.882
20	22.974

DATA SET 18 (T = 300 K)

C	ρ
71.68	41.60
81.23	25.20
90.62	17.66
100	9.94 (Sample No. 2)
100	9.50 (Sample No. 3)
100	8.46 (Sample No. 1)

* Not shown in figure.

3.5. Copper-Palladium Alloy System

The copper-palladium alloy system forms a continuous series of solid solutions over the entire range of compositions. However, ordered structures are formed at temperatures below about 775 K for compositions ranging from slightly below 10 to somewhat above 25 at.% (16 to 36 wt.%) palladium and at temperatures below about 975 K for compositions ranging from slightly below 30 to somewhat above 50 at.% (42 to 63 wt.%) palladium. The maxima of the temperatures of transformation suggest that these ordered structures are due to the formation of $PdCu_5$ and Pd_3Cu_5, respectively. Structure ordering decreases the resistivity of these alloys.

There are 124 sets of experimental data available for this system, which are listed in tables 30, 32, and 34, tabulated in tables 31, 33, and 35, and shown in figures 25, 26, and 27. However, since many of the resistivity measurements were made to determine the maximum degree of order and the minimum value of electrical resistivity of individual alloys in this system with various compositions, a large portion of the data were not useful for the purpose of this study.

For this alloy system most of the data for disordered alloys are room-temperature values. The data of Svensson [221] (Cu-Pd data set 7) agree quite well with the pure element data and were chosen as the best resistivity versus composition curve at 291 K. Johansson and Linde [222] (Cu-Pd data set 3) also reported resistivity values for the entire spectrum of compositions; these data support the shape of Svensson's curve but are generally higher. At low Pd concentrations the agreement between the data of these authors is fairly good, but at concentrations above 60 wt.% Pd there is almost a 20% discrepancy. Pott's data [223] (Cu + Pd data sets 58-61 and Pd + Cu data sets 34-39) at 291 K agree quite well with the values from Svensson's isotherm. Köster and Lang [224] (Cu-Pd data sets 16-19) and Jaumot and Sawatzky [225] (Cu-Pd data sets 11-15) reported values only slightly higher than Svensson's.

At temperatures above and below 291 K there were not much useful data to work with. Otter [226] (Cu + Pd data sets 9-12) reported resistivity versus temperature for low Pd concentrations, but his data at higher Pd concentrations were limited and conflicting. As a result, a procedure similar to that used for the Cu-Au alloy system was followed. Since Cu, Ag, and Au lie in the same

column of the periodic table, it was assumed that their alloying properties with Pd should be similar. Accordingly, for a point on the 291 K resistivity versus composition isotherm a curve was drawn parallel to the recommended resistivity versus temperature curve for the same atomic percent of Ag in Pd. As in the case of the Cu-Au alloy system, values obtained in this way are only provisional. In the Ag-Pd alloy system at 65 to 70 wt.% Pd, the smoothed resistivity values as a function of temperature showed a change in slope (i.e., + to - to +). When these curves were followed for the Cu-Pd alloy system, a peculiar shape in the resistivity versus composition curves resulted. Since these values are only provisional, the bends were taken out so that the slope was always positive, and a family of resistivity versus composition isotherms similar to that of the Au-Pd alloy system was obtained.

Supporting data for the provisional values obtained by the above procedure are provided by Otter [226] (Cu + Pd data sets 9-12) at all temperatures for low Pd concentrations. At low temperatures Bäcklund [227] (Cu + Pd data sets 1-3) provides supporting data. The greatest uncertainty occurs between 60 and 80 wt.% Pd where few data exist and pure element resistivity provides no guidance.

The resulting recommended or provisional electrical resistivity values for Cu, Pd, and for 25 Cu-Pd binary alloys are presented in table 29 and shown in figures 23, 24, and 27. The recommended values for Cu and for Pd are for well-annealed high-purity specimens, but those values for temperatures below about 100 K are applicable only to Cu and Pd having residual electrical resistivities as given at 1 K in table 29. The alloys for which the recommended or provisional values are generated are not ordered and have not been quenched or cold-worked severely. The values cover a full range of temperature from 1 K to 1200 K, and are not corrected for the thermal expansion of the material. The estimated uncertainties in the values for the various alloys and for different temperature ranges are explicitly stated in a footnote to table 29. The values for the alloys at temperatures below 150 K and above 400 K are indicated as provisional because their uncertainties are greater than ±5%.

TABLE 29. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM†

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Cu: 100.00% (100.00 At.%) Pd: 0.00% (0.00 At.%)		Cu: 99.50% (99.70 At.%) Pd: 0.50% (0.30 At.%)		Cu: 99.00% (99.40 At.%) Pd: 1.00% (0.60 At.%)		Cu: 97.00% (98.19 At.%) Pd: 3.00% (1.81 At.%)		Cu: 95.00% (96.95 At.%) Pd: 5.00% (3.05 At.%)		Cu: 90.00% (93.78 At.%) Pd: 10.00% (6.22 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	0.00206	1	0.280*‡	1	0.580*‡	1	1.62*‡	1	2.70*‡	1	5.32*‡
4	0.00200	4	0.280‡	4	0.580*‡	4	1.62*‡	4	2.70‡	4	5.32*‡
7	0.00200	7	0.280*‡	7	0.580*‡	7	1.62*‡	7	2.70*‡	7	5.32*‡
10	0.00202	10	0.280*‡	10	0.580*‡	10	1.62*‡	10	2.70*‡	10	5.32*‡
15	0.00218	15	0.280*‡	15	0.580*‡	15	1.62*‡	15	2.70*‡	15	5.32*‡
20	0.00280	20	0.280*‡	20	0.580*‡	20	1.62*‡	20	2.70*‡	20	5.32‡
25	0.00450	25	0.282*‡	25	0.580*‡	25	1.62*‡	25	2.70*‡	25	5.33‡
30	0.00830	30	0.289*‡	30	0.580*‡	30	1.62*‡	30	2.70*‡	30	5.34‡
40	0.0240	40	0.298*‡	40	0.592*‡	40	1.63*‡	40	2.70*‡	40	5.36‡
50	0.0520	50	0.313*‡	50	0.617*‡	50	1.66*‡	50	2.71*‡	50	5.38‡
60	0.0974	60	0.350*‡	60	0.652*‡	60	1.69*‡	60	2.74*‡	60	5.41‡
70	0.154	70	0.407*‡	70	0.699*‡	70	1.75*‡	70	2.80*‡	70	5.46‡
80	0.216	80	0.471*‡	80	0.763*‡	80	1.83*‡	80	2.86*‡	80	5.52‡
90	0.282	90	0.540*‡	90	0.837*‡	90	1.90*‡	90	2.93*‡	90	5.60‡
100	0.349	100	0.612*‡	100	0.909*‡	100	1.98*‡	100	2.99*‡	100	5.69‡
150	0.701	150	0.962*	150	1.26*	150	2.35*	150	3.35*	150	6.07
200	1.048	200	1.33*	200	1.60*	200	2.68*	200	3.70*	200	6.40
250	1.388	250	1.67*	250	1.94*	250	3.01*	250	4.05*	250	6.74
273	1.544	273	1.83	273	2.10	273	3.17	273	4.21	273	6.89
293	1.678	293	1.96	293	2.23	293	3.31	293	4.35	293	7.03
300	1.725	300	2.01	300	2.27	300	3.36	300	4.40	300	7.08
350	2.061	350	2.34*	350	2.59	350	3.69	350	4.74	350	7.41
400	2.398	400	2.67*	400	2.92	400	4.02	400	5.08	400	7.74
500	3.079	500	3.32*‡	500	3.59‡	500	4.67‡	500	5.72‡	500	8.40*‡
600	3.771	600	4.01*‡	600	4.29‡	600	5.32‡	600	6.39‡	600	9.05*‡
700	4.481	700	4.72*‡	700	5.00‡	700	6.03‡	700	7.09‡	700	9.20*‡
800	5.213	800	5.47*‡	800	5.74‡	800	6.78‡	800	7.82‡	800	10.39*‡
900	5.973	900	6.25*‡	900	6.51‡	900	7.53‡	900	8.60‡	900	11.12*‡
1000	6.766	1000	7.06*‡	1000	7.29*‡	1000	8.34*‡	1000	9.43*‡	1000	11.91*‡
1100	7.596	1100	7.88*‡	1100	8.11*‡	1100	9.20*‡	1100	10.30*‡	1100	12.74*‡
1200	8.470	1200	8.71*‡	1200	9.00*‡	1200	10.08*‡	1200	11.18*‡	1200	13.62*‡
1300	9.395										
1357.6	9.946(s)										
1358	21.01(ℓ)										
1700	24.41										

† Uncertainties in the electrical resistivity values are as follows:

100.00 Cu - 0.00 Pd: ±3% up to 100K, ±1% above 100K to 250K, ±0.5% above 250K to 350K, ±1% above 350K to 500K, ±4% above 500K to 1357.6K, and ±5% above 1357.6K.
99.50 Cu - 0.50 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
99.00 Cu - 1.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
97.00 Cu - 3.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
95.00 Cu - 5.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
90.00 Cu - 10.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 29. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Cu: 85.00% (90.47 At.%) Pd: 15.00% (9.53 At.%)		Cu: 80.00% (87.01 At.%) Pd: 20.00% (12.99 At.%)		Cu: 75.00% (83.40 At.%) Pd: 25.00% (16.60 At.%)		Cu: 70.00% (79.62 At.%) Pd: 30.00% (20.38 At.%)		Cu: 65.00% (75.67 At.%) Pd: 35.00% (24.33 At.%)		Cu: 60.00% (71.52 At.%) Pd: 40.00% (28.48 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	7.91*‡	1	10.43*‡	1	12.90*‡	1	15.30*‡	1	17.68*‡	1	20.01*‡
4	7.91*‡	4	10.43*‡	4	12.90‡	4	15.30‡	4	17.68‡	4	20.01‡
7	7.91*‡	7	10.43*‡	7	12.90*‡	7	15.30*‡	7	17.68*‡	7	20.01*‡
10	7.91*‡	10	10.43*‡	10	12.90*‡	10	15.30*‡	10	17.68*‡	10	20.01*‡
15	7.91*‡	15	10.43*‡	15	12.90*‡	15	15.30*‡	15	17.68*‡	15	20.01*‡
20	7.91‡	20	10.43*‡	20	12.90*‡	20	15.30‡	20	17.68*‡	20	20.01‡
25	7.92‡	25	10.43*‡	25	12.91*‡	25	15.31‡	25	17.68*‡	25	20.02‡
30	7.92‡	30	10.43*‡	30	12.91*‡	30	15.32‡	30	17.69*‡	30	20.03‡
40	7.94‡	40	10.44*	40	12.92*‡	40	15.34‡	40	17.70*‡	40	20.05‡
50	7.98‡	50	10.46*‡	50	12.96*‡	50	15.38‡	50	17.71*‡	50	20.10‡
60	8.02‡	60	10.50*‡	60	13.00*‡	60	15.42‡	60	17.74*‡	60	20.16‡
70	8.09‡	70	10.55*‡	70	13.05*‡	70	15.47‡	70	17.79*‡	70	20.23‡
80	8.16‡	80	10.61*‡	80	13.11*‡	80	15.53‡	80	17.85*‡	80	20.30‡
90	8.23‡	90	10.67*‡	90	13.19*‡	90	15.60‡	90	17.92*‡	90	20.38‡
100	8.30‡	100	10.74*‡	100	13.28*‡	100	15.67‡	100	17.98*‡	100	20.45‡
150	8.66	150	11.11*	150	13.62*	150	16.01	150	18.33*	150	20.82
200	9.00	200	11.47*	200	13.97*	200	16.37	200	18.71*	200	21.20
250	9.32	250	11.81*	250	14.32*	250	16.73	250	19.09*	250	21.56
273	9.48	273	11.99	273	14.48	273	16.87	273	19.26	273	21.73
293	9.61	293	12.12	293	14.62	293	17.01	293	19.41	293	21.87
300	9.66	300	12.16	300	14.67	300	17.06	300	19.46	300	21.92
350	10.01	350	12.51*	350	15.03*	350	17.41	350	19.82	350	22.30
400	10.36	400	12.87	400	15.39	400	17.78	400	20.17	400	22.69
500	11.00‡	500	13.51‡	500	16.07‡	500	18.47‡	500	20.82‡	500	23.39‡
600	11.64‡	600	14.10‡	600	16.70‡	600	19.10‡	600	21.44‡	600	24.01‡
700	12.29‡	700	14.78‡	700	17.32‡	700	19.72‡	700	22.06‡	700	24.61‡
800	12.98‡	800	15.49‡	800	17.96‡	800	20.35‡	800	22.68‡	800	25.23‡
900	13.70‡	900	16.18‡	900	18.60‡	900	21.00‡	900	23.31‡	900	25.86‡
1000	14.48*‡	1000	16.91*‡	1000	19.24*‡	1000	21.68*‡	1000	23.95*‡	1000	26.51*‡
1100	15.31*‡	1100	17.70*‡	1100	19.91*‡	1100	22.39*‡	1100	24.62*‡	1100	27.20*‡
1200	16.20*‡	1200	18.55*‡	1200	20.61*‡	1200	23.11*‡	1200	25.31*‡	1200	27.91*‡

† Uncertainties in the electrical resistivity values are as follows:

85.00 Cu - 15.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
80.00 Cu - 20.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
75.00 Cu - 25.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
70.00 Cu - 30.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
65.00 Cu - 35.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
60.00 Cu - 40.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 29. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Cu: 55.00% (67.18 At.%) Pd: 45.00% (32.82 At.%)		Cu: 50.00% (62.61 At.%) Pd: 50.00% (37.39 At.%)		Cu: 45.00% (57.81 At.%) Pd: 55.00% (42.19 At.%)		Cu: 40.00% (52.75 At.%) Pd: 60.00% (47.25 At.%)		Cu: 35.00% (47.41 At.%) Pd: 65.00% (52.59 At.%)		Cu: 30.00% (41.78 At.%) Pd: 70.00% (58.22 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	22.60*‡	1	25.53*‡	1	29.00*‡	1	32.63*‡	1	40.00*‡	1	44.19*‡
4	22.60*‡	4	25.53*‡	4	29.00*‡	4	32.63*‡	4	40.00*‡	4	44.19*‡
7	22.60*‡	7	25.53*‡	7	29.00*‡	7	32.63*‡	7	40.02*‡	7	44.23*‡
10	22.60*‡	10	25.53*‡	10	29.00*‡	10	32.65*‡	10	40.05*‡	10	44.27*‡
15	22.60*‡	15	25.54*‡	15	29.00*‡	15	32.68*‡	15	40.10*‡	15	44.31*‡
20	22.60*‡	20	25.55*‡	20	29.00*‡	20	32.73*‡	20	40.15*‡	20	44.36*‡
25	22.60*‡	25	25.56*‡	25	29.01*‡	25	32.77*‡	25	40.19*‡	25	44.40*‡
30	22.61*‡	30	25.57*‡	30	29.03*‡	30	32.81*‡	30	40.22*‡	30	44.43*‡
40	22.64*‡	40	25.59*‡	40	29.07*‡	40	32.91*‡	40	40.31*‡	40	44.51*‡
50	22.70*‡	50	25.63*‡	50	29.13*‡	50	33.01*‡	50	40.40*‡	50	44.60*‡
60	22.75*‡	60	25.71*‡	60	29.27*‡	60	33.12*‡	60	40.49*‡	60	44.70*‡
70	22.82*‡	70	25.80*‡	70	29.31*‡	70	33.22*‡	70	40.58*‡	70	44.79*‡
80	22.90*‡	80	25.89*‡	80	29.40*‡	80	33.32*‡	80	40.66*‡	80	44.86*‡
90	22.93*‡	90	25.98*‡	90	29.49*‡	90	33.43*‡	90	40.73*‡	90	44.94*‡
100	23.06*‡	100	26.07*‡	100	29.58*‡	100	33.53*‡	100	40.81*‡	100	45.03*‡
150	23.45*	150	26.52*	150	30.03*	150	34.05*	150	41.26*	150	45.47
200	23.87*	200	26.97*	200	30.48*	200	34.56*	200	41.69*	200	45.90
250	24.27*	250	27.42*	250	30.92*	250	35.08*	250	42.11*	250	46.31
273	24.47	273	27.62	273	31.12	273	35.31	273	42.31	273	46.50
293	24.63	293	27.79	293	31.30	293	35.51	293	42.48	293	46.66
300	24.68	300	27.86	300	31.36	300	35.57	300	42.53	300	46.71
350	25.05*	350	28.25	350	31.29	350	36.03	350	42.97	350	47.11
400	25.42*	400	28.64	400	32.22	400	36.47	400	43.38	400	47.47
500	26.12*‡	500	29.40‡	500	30.04‡	500	37.30‡	500	44.16‡	500	48.13*‡
600	26.78*‡	600	30.10‡	600	33.80‡	600	38.09‡	600	44.90‡	600	48.73*‡
700	27.41*‡	700	30.75‡	700	34.52‡	700	38.82‡	700	45.59‡	700	49.27*‡
800	28.05*‡	800	37.38‡	800	35.20‡	800	39.52‡	800	46.21‡	800	49.74*‡
900	28.72*‡	900	32.01‡	900	35.84‡	900	40.20‡	900	46.77‡	900	50.23*‡
1000	29.41*‡	1000	32.68*‡	1000	36.50*‡	1000	40.89*‡	1000	47.27*‡	1000	50.66*‡
1100	30.13*‡	1100	33.37*‡	1100	37.19*‡	1100	41.60*‡	1100	47.71*‡	1100	51.07*‡
1200	30.89*‡	1200	34.07*‡	1200	37.90*‡	1200	42.36*‡	1200	48.08*‡	1200	51.40*‡

† Uncertainties in the electrical resistivity values are as follows:

55.00 Cu - 45.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
50.00 Cu - 50.00 Pd: ±8% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
45.00 Cu - 55.00 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
40.00 Cu - 60.00 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
35.00 Cu - 65.00 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
30.00 Cu - 70.00 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 29. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Cu: 25.00% (35.82 At.%) Pd: 75.00% (64.18 At.%)		Cu: 20.00% (29.51 At.%) Pd: 80.00% (70.49 At.%)		Cu: 15.00% (22.81 At.%) Pd: 85.00% (77.19 At.%)		Cu: 10.00% (15.69 At.%) Pd: 90.00% (84.31 At.%)		Cu: 5.00% (8.10 At.%) Pd: 95.00% (91.90 At.%)		Cu: 3.00% (4.92 At.%) Pd: 97.00% (95.08 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	42.40*‡	1	36.26*‡	1	28.68*‡	1	20.10*‡	1	10.31*‡	1	6.20*‡
4	42.40*‡	4	36.26*‡	4	28.68*‡	4	20.10*‡	4	10.31*‡	4	6.20*‡
7	42.45*‡	7	36.33*‡	7	28.78*‡	7	20.17*‡	7	10.34*‡	7	6.20*‡
10	42.52*‡	10	36.43*‡	10	28.93*‡	10	20.28*‡	10	10.39*‡	10	6.20*‡
15	42.64*‡	15	36.59*‡	15	29.13*‡	15	20.44*‡	15	10.46*‡	15	6.21*‡
20	42.76*‡	20	36.75*‡	20	29.31*‡	20	20.58*‡	20	10.54*‡	20	6.25*‡
25	42.88*‡	25	36.90*‡	25	29.47*‡	25	20.72*‡	25	10.63*‡	25	6.30*‡
30	42.97*‡	30	37.03*‡	30	29.61*‡	30	20.85*‡	30	10.74*‡	30	6.38*‡
40	43.12*‡	40	37.29*‡	40	29.92*‡	40	21.11*‡	40	11.00*‡	40	6.60*‡
50	43.30*‡	50	37.54*‡	50	30.23*‡	50	21.40*‡	50	11.31*‡	50	6.89*‡
60	43.49*‡	60	37.80*‡	60	30.54*‡	60	21.70*‡	60	11.64*‡	60	7.24*‡
70	43.65*‡	70	38.06*‡	70	30.85*‡	70	22.00*‡	70	11.97*‡	70	7.66*‡
80	43.81*‡	80	38.32*‡	80	31.17*‡	80	22.31*‡	80	12.32*‡	80	8.09*‡
90	43.97*‡	90	38.58*‡	90	31.48*‡	90	22.64*‡	90	12.69*‡	90	8.52*‡
100	44.12*‡	100	38.83*‡	100	31.79*‡	100	23.00*‡	100	13.09*‡	100	8.97*‡
150	44.82*	150	40.06*	150	33.29	150	24.79*	150	15.12*	150	11.12*
200	45.45*	200	41.16*	200	34.66	200	26.52*	200	17.15*	200	13.20*
250	46.01*	250	42.13*	250	35.95	250	28.18*	250	19.11*	250	15.20*
273	46.25	273	42.54	273	36.52	273	28.90	273	20.00	273	16.09
293	46.45	293	42.87	293	36.99	293	29.51	293	20.75	293	16.85
300	46.52	300	42.98	300	37.16	300	29.73	300	21.07	300	17.11
350	46.99*	350	43.74*	350	38.28	350	31.19*	350	22.84*	350	18.96*
400	47.43*	400	44.47*	400	39.35	400	32.56*	400	24.54*	400	20.78*
500	48.20*‡	500	45.74*‡	500	41.27‡	500	35.09*‡	500	27.64*‡	500	24.20*‡
600	48.85*‡	600	46.79*‡	600	42.91‡	600	37.46*‡	600	30.49*‡	600	27.36*‡
700	49.41*‡	700	47.68*‡	700	44.34‡	700	39.65*‡	700	33.18*‡	700	30.25*‡
800	49.94*‡	800	48.48*‡	800	45.66‡	800	41.60*‡	800	35.70*‡	800	32.90*‡
900	50.42*‡	900	49.22*‡	900	46.90‡	900	43.35*‡	900	38.11*‡	900	35.38*‡
1000	50.85*‡	1000	49.91*‡	1000	48.10*‡	1000	45.02*‡	1000	40.45*‡	1000	37.78*‡
1100	51.21*‡	1100	50.54*‡	1100	49.23*‡	1100	46.62*‡	1100	42.68*‡	1100	40.11*‡
1200	51.49*‡	1200	51.07*‡	1200	50.26*‡	1200	48.11*‡	1200	44.76*‡	1200	42.33*‡

† Uncertainties in the electrical resistivity values are as follows:

25.00 Cu - 75.00 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
20.00 Cu - 80.00 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
15.00 Cu - 85.00 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
10.00 Cu - 90.00 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
5.00 Cu - 95.00 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
3.00 Cu - 97.00 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 29. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Cu: 1.00% (1.66 At.%) Pd: 99.00% (98.34 At.%)		Cu: 0.50% (0.83 At.%) Pd: 99.50% (99.17 At.%)		Cu: 0.00% (0.00 At.%) Pd: 100.00% (100.00 At.%)	
T	ρ	T	ρ	T	ρ
1	2.10*‡	1	1.10*‡	1	0.0200
4	2.10*‡	4	1.10*‡	4	0.0205
7	2.10*‡	7	1.10*‡	7	0.0217
10	2.10*‡	10	1.10*‡	10	0.0242
15	2.10*‡	15	1.10*‡	15	0.0346
20	2.11*‡	20	1.10*‡	20	0.0564
25	2.14*‡	25	1.13*‡	25	0.0938
30	2.21*‡	30	1.19*‡	30	0.151
40	2.45*‡	40	1.40*‡	40	0.335
50	2.78*‡	50	1.68*‡	50	0.607
60	3.15*‡	60	2.00*‡	60	0.940
70	3.52*‡	70	2.38*‡	70	1.32
80	3.92*‡	80	2.79*‡	80	1.75
90	4.34*‡	90	3.23*‡	90	2.19
100	4.78*‡	100	3.68*‡	100	2.63
150	6.91*	150	5.85*	150	4.81
200	9.00*	200	7.92*	200	6.89
250	11.00	250	9.91*	250	8.88
273	11.90	273	10.29	273	9.78
293	12.67	293	11.55	293	10.54
300	12.93*	300	11.81	300	10.80
350	14.82*	350	13.69*	350	12.66
400	16.68*	400	15.54*	400	14.46
500	20.19*‡	500	19.05*‡	500	17.89
600	23.41*‡	600	22.28*‡	600	21.10
700	26.42*‡	700	25.26*‡	700	24.10
800	29.25*‡	800	28.07*‡	800	26.89
900	31.[illegible]8*‡	900	30.68*‡	900	29.50
1000	34.27*‡	1000	33.09*‡	1000	31.92
1100	36.46*‡	1100	35.32*‡	1200	36.21
1200	38.50*‡	1200	37.40*‡	1400	39.80
				1600	42.70
				1827	45.14(s)
				1830	83.0(ℓ)
				2000	83.0

† Uncertainties in the electrical resistivity values are as follows:

1.00 Cu - 99.00 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
0.50 Cu - 99.50 Pd: ±10% below 150 K, ±5% from 150 to 400 K, and ±10% above 400 K.
0.00 Cu - 100.00 Pd: ±2% up to 40 K, ±1% above 40 K to 350 K, ±2% above 350 K to 1600 K, ±2.5% above 1600 K to 1827 K, and ±5% above 1827 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

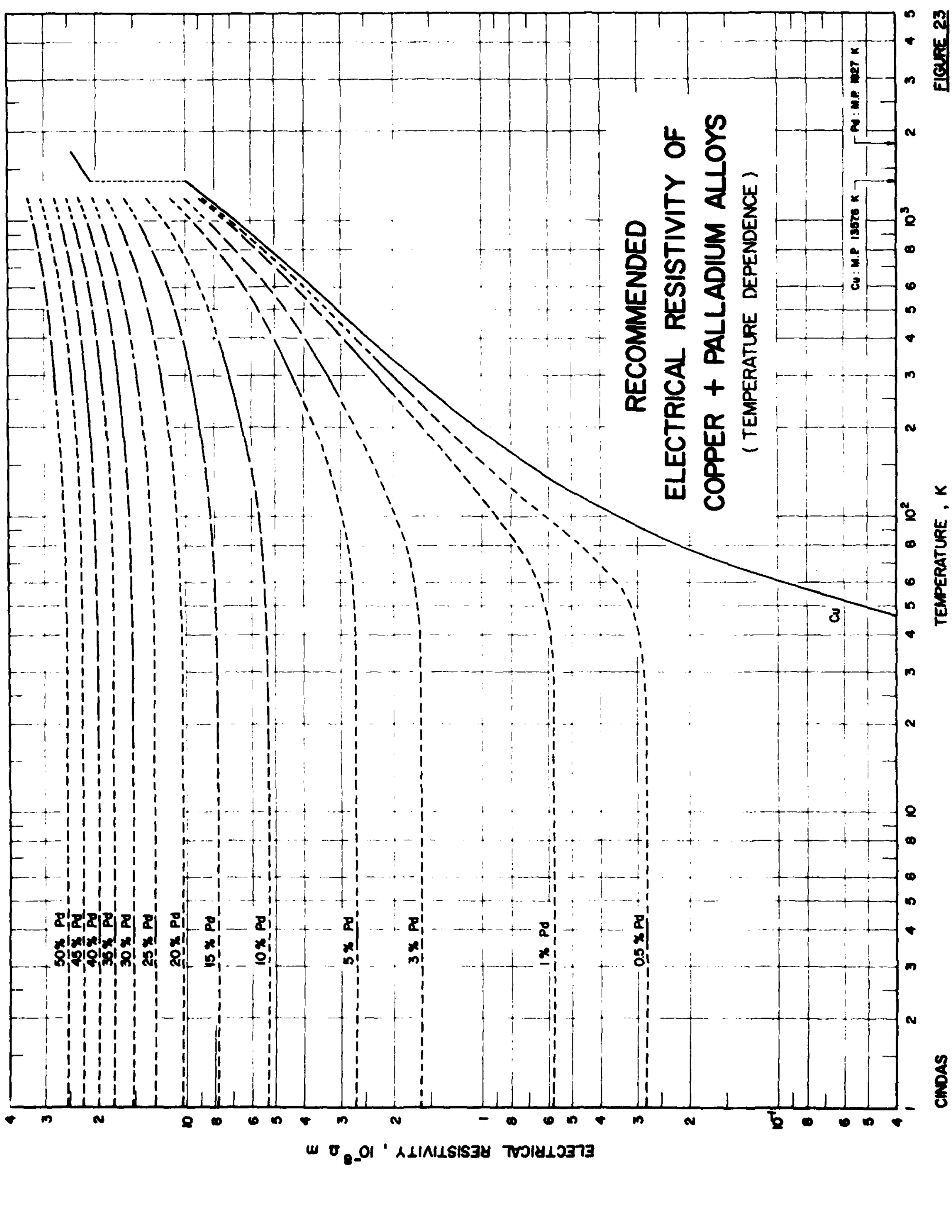

RECOMMENDED
ELECTRICAL RESISTIVITY OF
COPPER + PALLADIUM ALLOYS
(TEMPERATURE DEPENDENCE)
Cu : M.P. 1357.6 K
Pd : M.P. 1827 K
Cu
50% Pd
45% Pd
40% Pd
35% Pd
30% Pd
25% Pd
20% Pd
15% Pd
10% Pd
5% Pd
3% Pd
1% Pd
0.5% Pd
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE, K
CINDAS

FIGURE 23

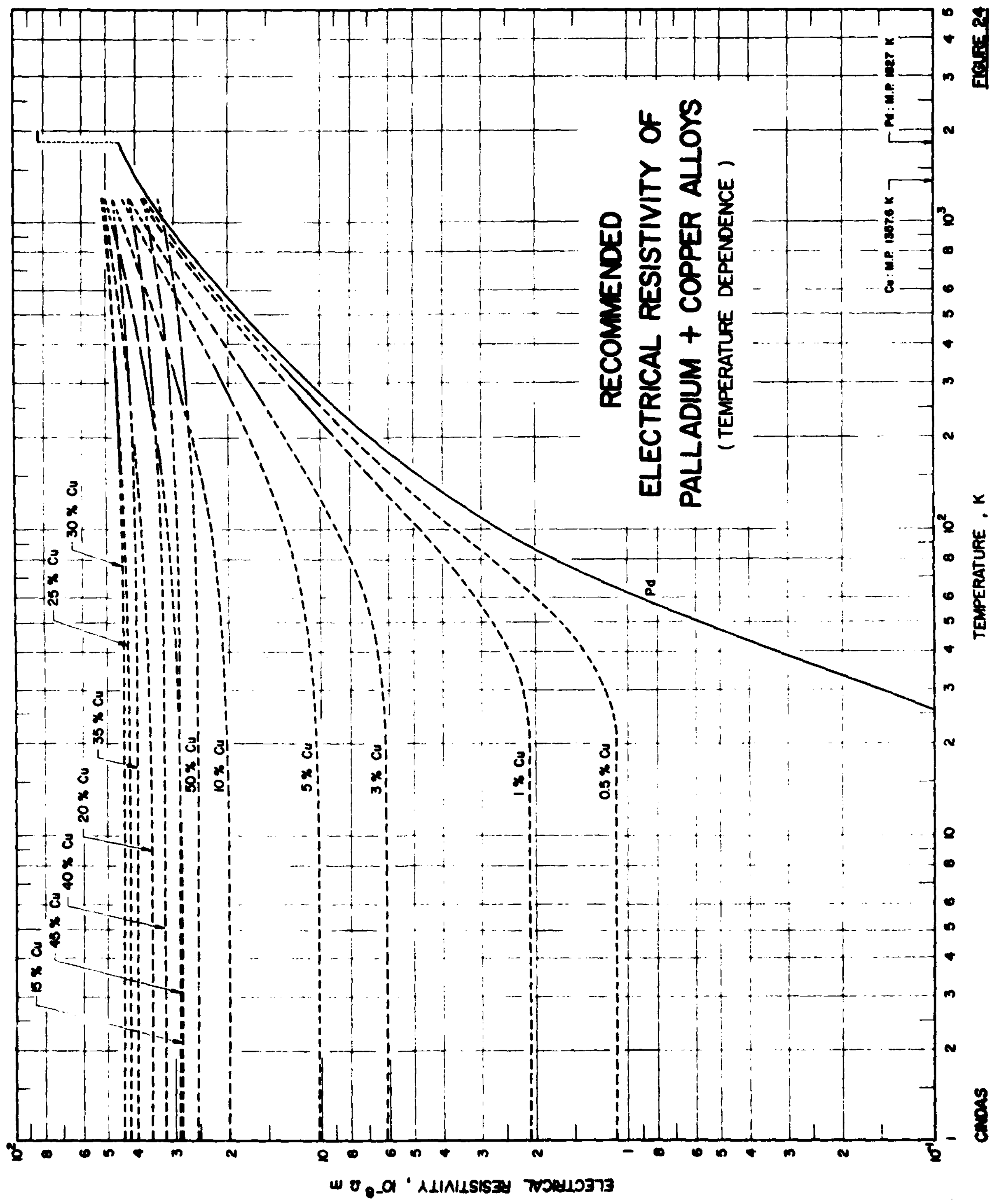
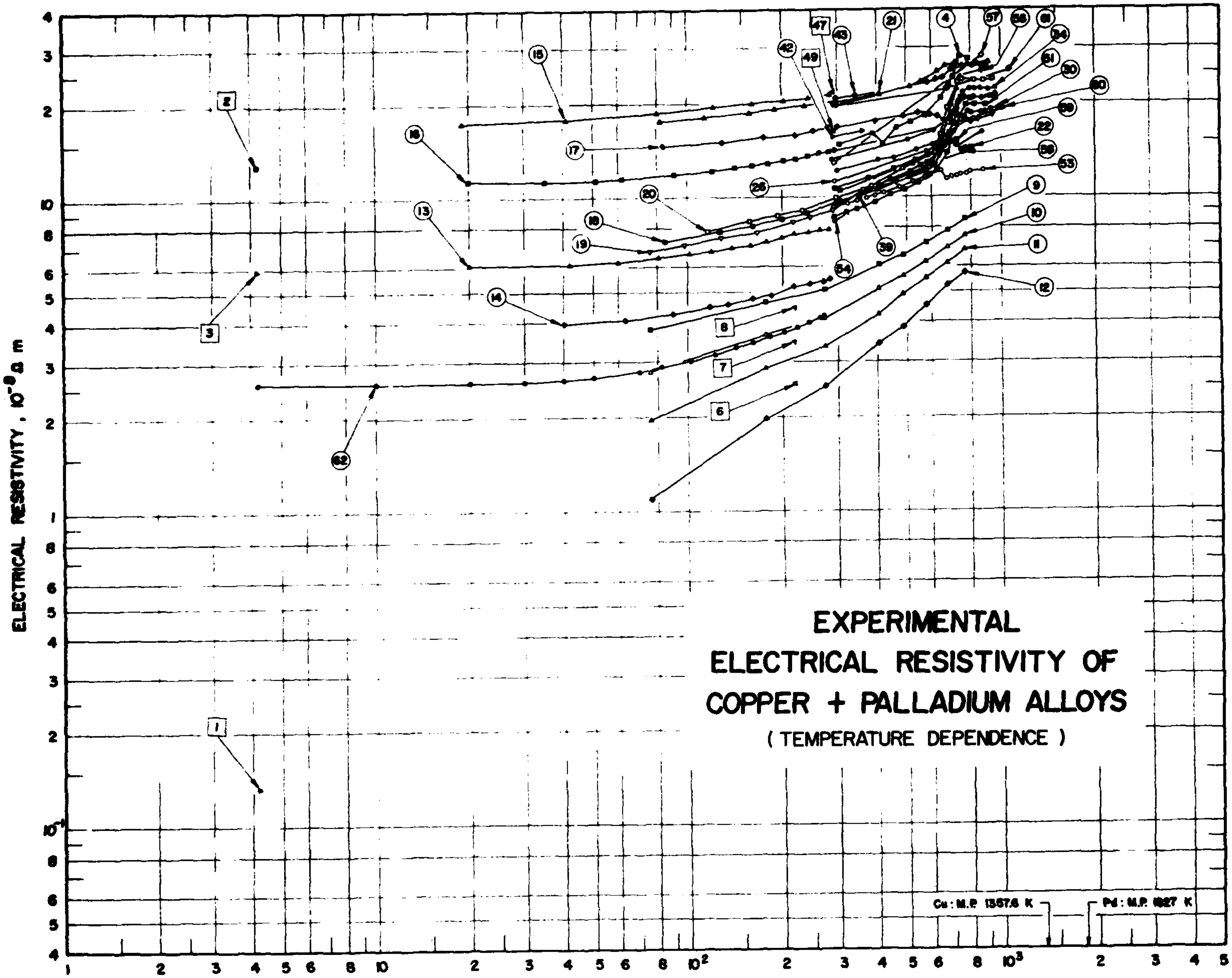

RECOMMENDED
ELECTRICAL RESISTIVITY OF
PALLADIUM + COPPER ALLOYS
(TEMPERATURE DEPENDENCE)
Pd : M.P. 1827 K
Cu : M.P. 1357.6 K
Pd
0.5 % Cu
1 % Cu
3 % Cu
5 % Cu
10 % Cu
50 % Cu
35 % Cu
20 % Cu
40 % Cu
45 % Cu
15 % Cu
25 % Cu
30 % Cu
TEMPERATURE , K
ELECTRICAL RESISTIVITY , 10^{-8} Ω m
CINDAS

FIGURE 24



CINDAS

TEMPERATURE , K

FIGURE 25

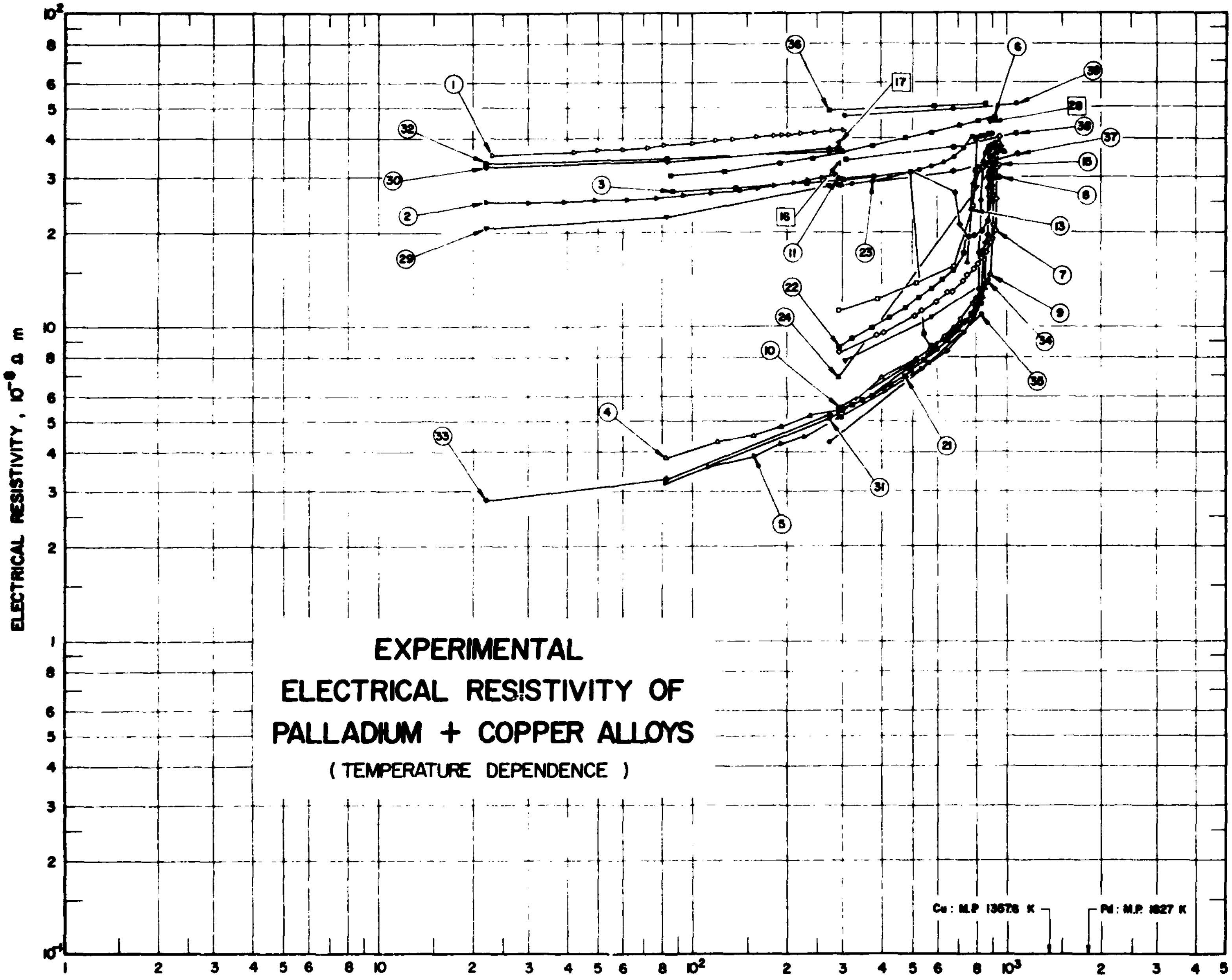

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
PALLADIUM + COPPER ALLOYS
(TEMPERATURE DEPENDENCE)
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE, K
Cu : M.P. 1357.6 K
Pd : M.P. 1827 K
CINDAS

FIGURE 26

TABLE 30. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + PALLADIUM ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Pd	Composition (continued), Specifications, and Remarks
1	227	Bäcklund, N.	1958		4.2			0.318	Calculated composition (0.19 a/o Pd); prepared from spectroscopically pure materials supplied by Johnson, Matthey and Co. Ltd., London, by melting the components in evacuated silica tubes in a high-frequency furnace; after slight rolling, the ingot homogenized at 800-900 C for about 2 hr, drawn to wires of about 0.2 mm in diameter, then annealed at about 500 C prior to the measurements.
2	227	Bäcklund, N.	1958		4.2			25.54	Calculated composition (17.0 a/o Pd); similar to the above specimen.
3	227	Bäcklund, N.	1958		4.2			25.54	Similar to the above specimen; ordered.
4	228	Yonemitsu, K. and Sato, T.	1958	A	306-792			35.82	Calculated composition (25 a/o Pd); 18.0 x 5.5 x 0.17 mm; measurements made while being cooled from temperature above Curie point with the cooling rate of 7.5, 8.5, 3, 20, and 5.0 K h^{-1} at 793-713 K, 713-708 K, 708-678 K, 678-573 K, and 573-room temperature, respectively.
5*	228	Yonemitsu, K. and Sato, T.	1958	A	306-611			35.82	The above specimen kept at 661 K for 27 hr, and at 539 K for 16 hr; same measuring condition as above.
6	126	Linde, J.O.	1932		291			1.66	Calculated composition (1.00 a/o Pd); prepared from Cu supplied by Hilgen, London, spectroscopically pure.
7	126	Linde, J.O.	1932		291			3.39	Calculated composition (2.05 a/o Pd); prepared from Cu supplied by Kahlbaum.
8	126	Linde, J.O.	1932		291			4.94	Calculated composition (3.01 a/o Pd); prepared from Cu supplied by Kahlbaum.
9	226	Otter, F.A., Jr.	1956		76-767			6.66	Calculated composition (4.09 a/o Pd); prepared from 99.99+ copper supplied by Vacuum Metals Corp. and 99.99+ palladium supplied by Bishop Platinum Company; components melted in vacuo in an alundum crucible within an induction furnace, super heated approximately 100 C above the melting point, homogenized in vacuo for twenty four hours at 900 C, ingot swaged or drawn to approximately thirty mils in diameter; annealed for about one hour at 500 to 550 C before measuring.
10	226	Otter, F.A., Jr.	1956		76-767			5.00	Calculated composition (3.05 a/o Pd); similar to the above specimen.
11	226	Otter, F.A., Jr.	1956		76-767			3.32	Calculated composition (2.01 a/o Pd); similar to the above specimen.
12	226	Otter, F.A., Jr.	1956		76-767			1.66	Calculated composition (1.00 a/o Pd); similar to the above specimen.
13	229	Ugodnikova, L.A., Volkenshtein, N.V., and Tsiovkin, Yu.N.	1971	A	20-280		84.31	15.69	Calculated composition (10 a/o Pd); cast and drawn; quenched in water from 600 K.
14	229	Ugodnikova, L.A., et al.	1971	A	40-284		91.9	8.1	Calculated composition (5 a/o Pd); similar to the above specimen.
15	229	Ugodnikova, L.A., et al.	1971	A	22-300		58.23	41.77	Calculated composition (30 a/o Pd); similar to the above specimen.
16	229	Ugodnikova, L.A., et al.	1971	A	19-282		70.49	29.51	Calculated composition (20 a/o Pd); similar to the above specimen.

* Not shown in figure.

TABLE 30. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + PALLADIUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Pd	Composition (continued), Specifications, and Remarks
17	230	Rennollet, G. and Seemann, H.J.	1969	A	84-960		70.5	29.5	Calculated composition (20 a/o Pd); cold-rolled; quenched from 700 C.
18	230	Rennollet, G. and Seemann, H.J.	1969	A	85-931		70.5	29.5	The above specimen heated to 750 C, then cooled to room temperature in 21 days.
19	230	Rennollet, G. and Seemann, H.J.	1969	A	76-944		77.19	22.81	Calculated composition (15 a/o Pd); cold-rolled.
20	230	Rennollet, G. and Seemann, H.J.	1969	A	85-942		64.18	35.82	Calculated composition (25 a/o Pd); cold-rolled.
21	230	Rennollet, G. and Seemann, H.J.	1969	A	82-917		58.23	41.77	Calculated composition (30 a/o Pd); cold-rolled.
22	123	Borelius, G., Johansson, C.H., and Linde, J.O.	1928	A	295-803			16.86	Calculated composition (10.8 a/o Pd); 20 x 1 x 1 mm; constituent metals melted in quartz tube, ingot heat-treated near melting point, cooled in a way to maintain rollable condition, rolled to 1 x 1 mm square wire, again heat-treated near melting point.
23*	123	Borelius, G., et al.	1928	A	524-803			16.86	The above specimen measured during cooling.
24*	123	Borelius, G., et al.	1928	A	524-764			16.86	The above specimen remeasured.
25*	123	Borelius, G., et al.	1928	A	287-771			16.86	The above specimen measured during cooling.
26	123	Borelius, G., et al.	1928	A	295-852			22.53	Calculated composition (14.8 a/o Pd); same dimensions, fabrication method, and heat-treatment as the above specimen.
27*	123	Borelius, G., et al.	1928	A	715-852			22.53	The above specimen measured during cooling.
28*	123	Borelius, G., et al.	1928	A	715-810			22.53	The above specimen remeasured.
29*	123	Borelius, G., et al.	1928	A	295-810			22.53	The above specimen measured during cooling.
30	123	Borelius, G., et al.	1928	A	300-980			25.54	Calculated composition (17.0 a/o Pd); same dimensions, fabrication method, and heat-treatment as the above specimen.
31*	123	Borelius, G., et al.	1928	A	295-980			25.54	The above specimen measured during cooling.
32*	123	Borelius, G., et al.	1928	A	298-982			28.20	Calculated composition (19.0 a/o Pd); same dimensions, fabrication method, and heat-treatment as the above specimen.
33*	123	Borelius, G., et al.	1928	A	293-893			30.80	Calculated composition (21.0 a/o Pd); similar to the above specimen.
34	123	Borelius, G., et al.	1928	A	289-962			30.80	The above specimen remeasured.
35*	123	Borelius, G., et al.	1928	A	294-962			30.80	The above specimen measured during cooling.
36*	123	Borelius, G., et al.	1928	A	299-959			33.34	Calculated composition (23.0 a/o) Pd; same dimensions, fabrication method, and heat-treatment as the above specimen.
37*	123	Borelius, G., et al.	1928	A	293-758			33.34	The above specimen measured during cooling.
38*	123	Borelius, G., et al.	1928	A	294-742			35.82	Calculated composition (25.0 a/o Pd); same dimensions, fabrication method, and heat-treatment as the above specimen.
39	123	Borelius, G., et al.	1928	A	351-742			35.82	The above specimen measured during cooling.
40*	123	Borelius, G., et al.	1928	A	290-894			35.82	The above specimen remeasured.

* Not shown in figure.

TABLE 30. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + PALLADIUM ALLOYS (*Temperature Dependence*) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Pd	Composition (continued), Specifications, and Remarks
41*	123	Borelius, G., Johansson, C.H., and Linde, J.O.	1928	A	728-754			35.82	The above specimen measured during cooling.
42	123	Borelius, G., et al.	1928	A	293, 363			35.82	The above specimen.
43	123	Borelius, G., et al.	1928	A	296-899			39.44	Calculated composition (28.0 a/o Pd); same dimensions, fabrication method, and heat-treatment as the above specimen.
44*	123	Borelius, G., et al.	1928	A	299-692			39.44	The above specimen remeasured.
45*	123	Borelius, G., et al.	1928	A	670-750			39.44	The above specimen.
46*	123	Borelius, G., et al.	1928	A	285-750			39.44	The above specimen measured during cooling.
47	131	Röhl, H.	1933		291.2			35.82	Calculated composition (25 a/o Pd); 0.3 cm diameter x 11 cm long; obtained from Firma Siebert-Hanan; drawn.
48*	131	Röhl, H.	1933		291.2			35.82	The above specimen quenched.
49	131	Röhl, H.	1933		291.2			35.82	The above specimen tempered.
50*	131	Röhl, H.	1933		291.2			35.82	The above specimen requenched.
51	231	Taylor, R.	1934	A	293-898			29.50	Calculated composition (19.95 a/o Pd); electrolytic copper (major impurity 0.002 [illegible]) and palladium sponge melted in high vacuum in a high frequency induction furnace, cooled and drawn into wires.
52*	231	Taylor, R.	1934	A	293-898			29.50	The above specimen measured at decreasing temperatures.
53	231	Taylor, R.	1934	A	293-873			15.65	Calculated composition (9.95 a/o Pd); similar to the above specimen.
54	231	Taylor, R.	1934	A	293, 873			23.10	Calculated composition (15 a/o Pd); similar to the above specimen.
55*	231	Taylor, R.	1934	A	293, 873			36.08	Calculated composition (25 a/o Pd); similar to the above specimen.
56	231	Taylor, R.	1934	A	293, 873			41.96	Calculated composition (30 a/o Pd); similar to the above specimen.
57	231	Taylor, R.	1934	A	293, 873			47.74	Calculated composition (35 a/o Pd); similar to the above specimen.
58	223	Pott, F.P.	1958		309-753			24.2	Calculated composition (16 a/o Pd); annealed at 600 to 700 C for 2 hr; ordered.
59	223	Pott, F.P.	1958		307-722			24.2	Similar to the above specimen but disordered.
60	223	Pott, F.P.	1958		292-1012			35.8	Calculated composition (25 a/o Pd); similar to the above specimen but ordered.
61	223	Pott, F.P.	1958		298-1073			35.8	Similar to the above specimen but disordered.
62*	186	Kierspe, W.	1967	V	4.2-273			4.92	Calculated composition (3.0 a/o Pd); 3 mm diameter cylindrical specimen.

* Not shown in figure.

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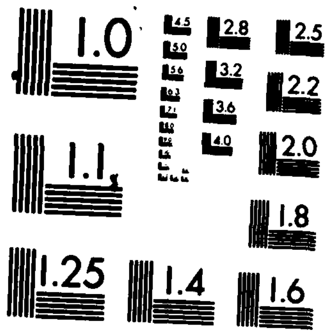

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TABLE 31. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + PALLADIUM ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

DATA SET 1

T	ρ
4.2	0.1345

DATA SET 2

T	ρ
4.2	12.943

DATA SET 3

T	ρ
4.2	5.968

DATA SET 4

T	ρ
306.2	14.8
394.2	16.0
422.2	14.9
468.2	16.8
517.2	17.5
572.2	18.2
606.2	18.9*
627.2	19.7*
649.2	20.8
676.2	22.4*
678.2	22.5*
681.2	22.7*
686.2	23.0*
692.2	23.4*
694.2	23.5*
702.2	24.1
705.2	24.4*
712.2	25.0*
717.2	25.8
723.2	27.0*
731.2	27.4*
737.2	28.1
749.2	28.2*
758.2	28.1*
768.2	28.0*
782.2	28.1*
792.2	27.9

DATA SET 5*

T	ρ
305.2	14.9
549.2	19.8
611.2	20.2

DATA SET 6

T	ρ
291.2	2.569

DATA SET 7

T	ρ
291.2	3.492

DATA SET 8

T	ρ
291.2	4.496

DATA SET 9

T	ρ
76.2	3.84
176.2	4.56
273.2	5.10
407.2	6.10
488.2	6.58
577.2	7.18
673.2	7.83
767.2	8.50

DATA SET 10

T	ρ
76.2	2.79
176.2	3.68
273.2	4.13
407.2	5.12
488.2	5.63
577.2	6.29
673.2	6.97
767.2	7.56

DATA SET 11

T	ρ
76.2	1.97
176.2	2.87
273.2	3.38
407.2	4.24
488.2	4.92
577.2	5.55
673.2	6.19
767.2	6.82

DATA SET 12

T	ρ
76.2	1.11
176.2	1.97
273.2	2.51
407.2	3.42
488.2	3.86
577.2	4.51
673.2	5.22
767.2	5.78

DATA SET 13

T	ρ
20	6.1
42	6.1
60	6.2
81	6.4
102	6.6
119	6.7
138	6.9
159	7.0
179	7.2
200	7.4
220	7.6
241	7.7
261	7.8
280	7.9

DATA SET 14

T	ρ
40	4.0
63	4.1
90	4.3
118	4.5
135	4.6
161	4.8
185	4.9
218	5.2
245	5.3
270	5.4
284	5.5

DATA SET 15

T	ρ
19	17.5
41	17.9
80	18.7

DATA SET 15 (cont.)

T	ρ
122	19.5
161	20.0
202	20.4
243	20.8
282	21.4

DATA SET 16

T	ρ
20	11.4
35	11.3
51	11.4
62	11.6
91	11.9
120	12.2
142	12.5
161	12.7
183	12.9
202	13.2
222	13.4
241	13.6
263	13.8
281	14.0

DATA SET 17

T	ρ
84	14.7
130	15.2
176	15.6
221	15.9
253	16.4
300	16.8
399	17.6
490	18.3
547	18.6
597	18.5
630	18.2
660	17.6
696	17.6
726	19.1*
765	20.9*
827	20.8*
874	20.9*
960	21.4*

DATA SET 18

T	ρ
85	7.3
128	7.8
161	8.1
200	8.5
240	8.9
299	9.6
410	10.9
443	11.4
514	12.1
553	12.6
589	12.9
620	13.4*
650	14.1
659	14.8*
674	15.5
685	16.0*
702	16.8
726	18.3
750	20.8*
800	20.7*
860	20.8*
889	20.9*
931	21.0*

DATA SET 19

T	ρ
76	6.75
98	7.04
129	7.42
167	7.75
216	8.36
245	8.62
290	9.04
364	10.06
462	11.01
571	12.01
614	12.63
636	13.56
668	14.57
715	16.12
763	17.52
776	17.44*
804	17.44
849	17.46
880	17.91*
944	18.25

DATA SET 20

T	ρ
85	7.39*
116	7.80
158	8.42
194	8.79
232	9.09
298	9.91
388	10.91
487	12.04
587	13.17*
618	13.95
646	15.98
679	19.04
730	23.40
740	23.74
755	23.77*
778	23.62*
836	23.66
881	23.75
942	23.90

DATA SET 21

T	ρ
82	17.56
114	18.13
158	18.68
190	19.02
237	19.54
299	20.01
408	21.42
512	22.66
558	23.38
627	25.08
643	26.33*
667	26.38
701	26.38
725	26.46*
783	26.55
843	26.67
917	27.03

DATA SET 22

T	ρ
295	10.71
379	11.56
486	12.38

* Not shown in figure.

TABLE 31. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + PALLADIUM ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 22 (cont.)	
532	13.14
586	13.66
616	14.01
637	14.28*
662	14.63*
673	14.83
682	14.96*
690	15.00
696	15.00*
701	15.00*
708	14.97
715	14.88*
722	14.73*
728	14.54*
737	14.31
743	14.27*
749	14.27*
756	14.32*
764	14.36*
771	14.36*
781	14.38
803	14.47
DATA SET 23*	
524	13.47
540	13.59
580	13.84
596	13.94
604	14.04
630	14.06
638	14.06
647	14.06
653	14.06
661	14.08
668	14.07
679	14.07
687	14.07
693	14.07
698	14.09
703	14.12
710	14.10
716	14.14
727	14.21
743	14.27
749	14.27
756	14.32

T	ρ
DATA SET 23 (cont.)*	
771	14.36
771	14.36
781	14.38
803	14.47
DATA SET 24*	
524	13.47
540	13.59
580	13.84
596	13.94
604	14.04
636	14.26
666	14.41
674	14.44
690	14.49
703	14.46
718	14.28
728	14.25
743	14.27
749	14.27
756	14.32
764	14.36
DATA SET 25*	
287	11.76
524	13.47
540	13.59
580	13.84
596	13.94
604	14.04
630	14.06
638	14.06
647	14.06
653	14.06
661	14.08
668	14.07
679	14.07
687	14.07
693	14.07
698	14.09
703	14.12
710	14.10
716	14.14
727	14.21
743	14.27

T	ρ
DATA SET 25 (cont.)*	
749	14.27
756	14.32
771	14.36
DATA SET 26	
295	11.34
580	14.01
630	14.51*
651	14.83*
663	15.13*
674	15.45*
684	15.74*
692	15.90*
701	16.05*
706	16.19*
714	16.31*
732	16.93
741	17.16*
751	17.42*
762	17.74*
771	18.03*
776	18.01*
782	17.82*
790	17.52*
798	17.49
805	17.55*
814	17.58
8[illegible]	17.60*
82[illegible]	17.60*
837	17.64*
852	17.70*
DATA SET 27*	
715	15.64
731	16.45
757	17.40
763	17.70
768	17.62
774	17.49
780	17.45
790	17.52
798	17.49
805	17.55
814	17.59
820	17.60

T	ρ
DATA SET 27 (cont.)*	
828	17.60
837	17.64
852	17.70
DATA SET 28*	
715	15.64
731	16.45
757	17.40
762	17.76
766	17.95
773	18.02
777	18.02
782	17.83
788	17.56
796	17.47
810	17.47
DATA SET 29*	
295	10.56
708	15.75
721	16.23
751	17.29
763	17.72
768	17.65
774	17.52
781	17.46
787	17.40
797	17.45
810	17.47
DATA SET 30	
300	12.10
404	13.10
459	13.45
536	14.15
566	14.40*
601	14.73
624	14.96*
673	15.76
711	16.55*
738	17.16
755	17.72
766	18.00*
775	18.45*

T	ρ
DATA SET 30 (cont.)	
782	18.84*
784	18.66*
790	18.61*
799	18.55
808	18.55*
818	18.55
830	18.57*
839	18.62*
849	18.64*
863	18.65
880	18.75*
883	18.70*
894	18.81*
907	18.87*
929	18.97
939	19.02*
956	19.11*
968	19.15*
980	19.18
DATA SET 31*	
295	10.16
666	13.84
693	14.63
731	16.02
741	16.31
747	16.77
751	17.04
757	17.40
763	17.78
768	18.24
770	18.67
773	18.87
784	18.66
790	18.61
799	18.55
808	18.55
818	18.55
830	18.57
839	18.62
849	18.64
863	18.65
880	18.75
883	18.70
894	18.81
907	18.87

T	ρ
DATA SET 31 (cont.)*	
929	18.97
939	19.02
956	19.11
968	19.15
980	19.18
DATA SET 32*	
298	13.05
542	15.49
586	15.92
611	16.18
630	16.37
645	16.59
659	16.89
670	17.06
683	17.31
695	17.56
704	17.79
720	18.08
735	18.71
747	19.18
757	19.81
766	20.25
771	20.57
778	20.67
784	20.66
791	20.62
800	20.58
811	20.58
820	20.58
827	20.61
836	20.63
849	20.73
861	20.78
873	20.78
884	20.78
893	20.78
901	20.78
910	20.74
917	20.76
924	20.76
929	20.81
933	20.77
939	20.86
956	20.92
965	20.86

* Not shown in figure.

TABLE 31. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + PALLADIUM ALLOYS (Temperature Dependence) (continued)

DATA SET 32 (cont.)*

T	ρ
972	20.89
982	20.94

DATA SET 33*

T	ρ
293	18.13
306	18.26
360	18.79
428	19.46
515	20.10
526	20.38
569	20.54
593	20.67
606	20.78
619	20.92
636	21.15
650	21.41
667	21.41
682	21.07
693	20.50
706	20.12
717	20.12
725	20.31
728	20.53
733	20.85
737	21.09
740	21.26
747	21.57
753	21.80
763	21.96
777	21.85
793	21.80
800	21.73
807	21.76
839	21.73
870	21.84
881	21.90
893	21.92

DATA SET 34

T	ρ
289	13.39
505	15.43
526	15.82*
618	16.46
667	17.07
695	18.27

DATA SET 34 (cont.)

T	ρ
730	19.38*
732	20.20
736	20.55*
740	20.79*
746	21.03*
752	21.33*
755	21.68
760	21.91*
763	22.07*
768	22.14*
785	22.08*
794	22.08*
800	22.08
813	22.07*
822	22.07*
830	22.07
836	22.12*
849	22.16*
858	22.21*
867	22.21
878	22.23*
886	22.18*
893	22.16*
905	22.12*
915	22.08*
923	22.08
933	22.08*
940	22.17*
947	22.17*
955	22.23*
962	22.20

DATA SET 35*

T	ρ
294	13.26
615	16.48
677	18.20
699	19.06
712	19.58
724	20.29
727	20.51
732	20.82
738	21.04
742	21.26
747	21.54
753	21.78
764	21.96

DATA SET 35 (cont.)*

T	ρ
778	21.88
793	21.80
801	21.70
807	21.78
838	21.73
871	21.84
881	21.91
893	21.93
915	22.08
923	22.08
933	22.08
940	22.17
947	22.17
955	22.23
962	22.20

DATA SET 36*

T	ρ
299	13.35
395	14.27
435	14.60
504	15.16
546	15.60
586	16.02
616	16.38
627	16.62
647	17.07
671	17.55
678	17.86
688	18.11
698	18.45
706	18.81
717	19.28
723	19.65
730	20.13
735	20.53
740	20.78
743	21.10
748	21.83
751	22.12
756	22.49
760	22.74
762	22.88
768	22.97
781	22.86
790	22.79
800	22.70

DATA SET 36 (cont.)*

T	ρ
807	22.70
813	22.74
820	22.66
830	22.66
850	22.67
859	22.67
869	22.71
890	22.77
901	22.83
910	22.87
920	22.87
929	22.94
937	22.94
959	23.08

DATA SET 37*

T	ρ
293	13.05
649	17.04
656	17.31
678	18.16
703	19.45
718	20.45
727	21.19
735	21.78
738	22.13
744	22.57
749	22.78
753	22.86
758	22.96

DATA SET 38*

T	ρ
294	15.93
330	16.25
536	17.94
568	18.14
588	18.24
609	18.29
654	19.16
680	20.30
694	21.23
701	21.51
714	22.23
723	22.90
733	23.44
736	23.70
742	24.02

DATA SET 39

T	ρ
351	10.09
362	10.18*
406	10.64
510	11.63
522	11.77*
537	11.95*
565	12.33
585	12.62*
593	12.79*
603	12.95
603	13.14*
611	13.35*
618	13.64*
634	14.33
645	14.71*
650	15.12*
655	15.18*
676	16.66*
679	16.88*
682	17.11*
686	17.42*
688	17.76*
689	18.07
698	19.88*
703	20.87
721	22.23*
728	22.93*
736	23.70
742	24.02*

DATA SET 40*

T	ρ
290	12.93
470	14.83
502	15.10
555	15.61
597	16.06
627	16.51
653	17.20
664	17.78
682	18.56
701	19.88
705	20.32
713	20.85
718	21.29
723	21.71
728	22.17
733	22.58

DATA SET 40 (cont.)*

T	ρ
737	22.94
742	23.42
747	23.92
750	24.15
762	24.32
771	24.27
789	24.27
769	24.13
796	24.19
807	24.14
816	24.20
831	24.14
844	24.11
864	24.11
880	24.17
894	24.20

DATA SET 41*

T	ρ
728	23.47
732	23.76
738	24.14
742	24.32
749	24.37
754	24.31

DATA SET 42

T	ρ
293	15.74
363	16.34

DATA SET 43

T	ρ
296	20.65
344	21.23
519	22.73*
572	23.25*
582	23.37*
597	23.42*
613	23.50*
620	23.57
626	23.59*
636	23.69*
646	23.61
655	24.01*
664	24.30
677	24.78*
698	25.54

* Not shown in figure.

TABLE 31. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + PALLADIUM ALLOYS (Temperature Dependence) (continued)

DATA SET 43 (cont.)

T	ρ
702	25.99*
706	26.19*
718	26.23*
729	26.26*
732	26.35*
742	26.23*
748	26.23
757	26.17*
768	26.17*
778	26.17*
786	26.17*
794	26.15*
803	26.15
812	26.19*
819	26.19*
829	26.25*
837	26.25*
847	26.25*
852	26.27*
859	26.33*
869	26.28*
877	26.37*
888	26.44
899	26.44

DATA SET 44*

T	ρ
299	21.46
423	22.69
514	23.54
540	23.70
566	23.95
592	24.17
609	24.27
632	24.51
651	24.75
674	25.08
692	25.36

DATA SET 45*

T	ρ
670	23.69
676	23.93
695	25.19
707	25.85
717	26.25
728	26.25
732	26.35

DATA SET 45 (cont.)*

T	ρ
736	26.23
742	26.21
750	26.21

DATA SET 46*

T	ρ
285	17.68
574	20.50
617	21.29
658	23.22
671	24.54
686	25.77
706	26.18
718	26.23
728	26.25
732	26.35
736	26.23
742	26.21
750	26.21

DATA SET 47

T	ρ
291.2	21.71

DATA SET 48*

T	ρ
291.2	21.71

DATA SET 49

T	ρ
291.2	16.26

DATA SET 50*

T	ρ
291.2	22.93

DATA SET 51

T	ρ
293.2	8.65*
298.[illegible]	8.69
323.[illegible]	8.91
348.2	9.17
373.2	9.39*
398.2	9.65
423.2	9.87*
448.2	10.10
473.2	10.36*
498.2	10.56

DATA SET 51 (cont.)

T	ρ
523.2	10.82*
548.2	11.07
573.2	11.25*
598.2	11.84
623.2	12.45
648.2	13.15
673.2	13.97*
698.2	15.03*
723.2	16.36
748.2	18.31*
773.2	19.58
798.2	19.51*
823.2	19.51
848.2	19.53*
873.2	19.58*
898.2	19.69

DATA SET 52*

T	ρ
293.2	15.41
298.2	15.47
323.2	15.61
348.2	15.77
373.2	15.91
398.2	16.09
423.2	16.23
448.2	16.42
473.2	16.58
498.2	16.74
523.2	16.88
548.2	17.05
573.2	17.20
598.2	15.92
623.2	14.70
648.2	14.66
673.2	14.84
698.2	15.68
723.2	16.64
748.2	17.92
773.2	19.63
798.2	19.51
823.2	19.51
848.2	19.53
873.2	19.58
898.2	19.69

DATA SET 53

T	ρ
293.2	9.27*
298.2	9.31
323.2	9.51
348.2	9.76
313.2	9.95
398.2	10.15
423.2	10.39
448.2	10.59*
473.2	10.83
498.2	11.04*
523.2	11.26
548.2	11.46*
573.2	11.67
598.2	11.95*
623.2	12.30
648.2	12.08*
673.2	11.44
698.2	11.59
723.2	11.70
748.2	11.82
773.2	11.97
798.2	12.09
873.2	12.30

DATA SET 54

T	ρ
293	8.4
873	16.2

DATA SET 55*

T	ρ
293	9.7
873	22.9

DATA SET 56

T	ρ
293	19.9
873	25.4

DATA SET 57

T	ρ
293	12.9
873	28.4

DATA SET 58

T	ρ
309	9.7
573	12.4
753	13.9

DATA SET 59

T	ρ
307	10.5
524	12.9
722	15.2

DATA SET 60

T	ρ
292	14.2
714	17.1
1012	19.3

DATA SET 61

T	ρ
298	19.7
673	22.4
1073	25.6

DATA SET 62*

T	ρ
4.2	2.5862
10	2.5865
20	2.5901
30	2.6052
40	2.6370
50	2.6849
70	2.8092
83	2.9047
103	3.0440
123	3.1847
143	3.3258
163	3.4636
183	3.6005
203	3.7351
223	3.8703
243	4.0055
263	4.1351
273	4.2018

* Not shown in figure.

TABLE 32. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + COPPER ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Pd	Cu	Composition (continued), Specifications, and Remarks
1	229	Ugodnikova, L.A., Volkenshtein, N.V., and Tsiovkin, Yu. N.	1971	A	23-304		71.49	28.51	Calculated composition (40 a/o Cu); cast and drawn; quenched in water from 600 K.
2	229	Ugodnikova, L.A., et al.	1971	A	22-285		86.95	13.05	Calculated composition (20 a/o Cu); similar to the above specimen.
3	230	Rennollet, G. and Seemann, H.J.	1969	A	87-959		54.8	45.20	Calculated composition (58 a/o Cu); cold-rolled; quenched from 700 C.
4	230	Rennollet, G. and Seemann, H.J.	1969	A	82-980		54.8	45.20	The above specimen heated to 750 C, then cooled to room temperature in 21 days.
5	230	Rennollet, G. and Seemann, H.J.	1969	A	82-951		57.78	42.22	Calculated composition (55 a/o Cu); cold-rolled.
6	230	Rennollet, G. and Seemann, H.J.	1969	A	85-917		86.95	13.05	Calculated composition (20 a/o Cu); cold-rolled.
7	123	Borelius, G., Johansson, C.H., and Linde, J.O.	1928	A	293-947		62.42		Calculated composition (49.8 a/o Pd); 20 x 1 x 1 mm; metals melted in quartz tube, ingot heat-treated near melting point, cooled in a way to maintain rollable condition, rolled to 1 x 1 square wire, again heat-treated near melting point.
8	123	Borelius, G., et al.	1928	A	834-942		62.42		The above specimen measured during cooling.
9	123	Borelius, G., et al.	1928	A	297-926		56.72		Calculated composition (43.9 a/o Pd); same dimensions, fabrication method, and heat-treatment as the above specimen.
10	123	Borelius, G., et al.	1928	A	293-926		56.72		The above specimen measured during cooling.
11	123	Borelius, G., et al.	1928	A	292-897		50.65		Calculated composition (38.0 a/o Pd); same dimensions, fabrication method, and heat-treatment as the above specimen.
12*	123	Borelius, G., et al.	1928	A	859-906		50.65		The above specimen measured during cooling.
13	123	Borelius, G., et al.	1928	A	748-952		50.65		The above specimen measured during cooling.
14*	123	Borelius, G., et al.	1928	A	748-942		50.65		The above specimen remeasured.
15	123	Borelius, G., et al.	1928	A	291-942		50.65		The above specimen measured during cooling.
16	131	Röhl, H.	1933		291.2		62.58	37.42	Calculated composition (50 a/o Pd); 0.3 cm diameter x 11 cm long; obtained from Firma Siebert-Hanau; cold-drawn.
17	131	Röhl, H.	1933		291.2		62.58	37.42	The above specimen quenched.
18*	131	Röhl, H.	1933		291.2		62.58	37.42	The above specimen tempered.
19*	131	Röhl, H.	1933		291.2		57.81	42.19	Calculated composition (55 a/o Cu); same dimensions and supplier as the above specimen; quenched.
20*	131	Röhl, H.	1933		291.2		57.81	42.19	The above specimen tempered.
21	231	Taylor, R.	1934	A	293-898		54.69	45.31	Calculated composition (41.75 a/o Pd); electrolytic copper (major impurity 0.002 Fe) and palladium sponge melted in high vacuum, cooled, and drawn into wires.
22	231	Taylor, R.	1934	A	293-873		62.01	37.99	Calculated composition (49.24 a/o Pd); similar to the above specimen.

* Not shown in figure.

TABLE 32. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + COPPER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Pd	Cu	Composition (continued), Specifications, and Remarks
23	231	Taylor, R.	1934	A	293-898		62.01	27.99	The above specimen measured during cooling.
24	231	Taylor, R.	1934	A	293, 873		52.57	47.43	Calculated composition (40 a/o Pd); similar to the above specimen.
25*	231	Taylor, R.	1934	A	293, 873		56.59	43.41	Calculated composition (42.5 a/o Pd); similar to the above specimen.
26*	231	Taylor, R.	1934	A	293, 873		58.21	41.79	Calculated composition (45 a/o Pd); similar to the above specimen.
27*	231	Taylor, R.	1934	A	293, 873		63.02	36.98	Calculated composition (50 a/o Pd); similar to the above specimen.
28	231	Taylor, R.	1934	A	873		67.49	32.51	Calculated composition (55 a/o Pd); similar to the above specimen.
29	128	Grüneisen, E. and Reddemann, H.	1934		22-273			9.2	Calculated composition (14.5 a/o Cu); polycrystalline; obtained from Heraeus.
30	128	Grüneisen, E. and Reddemann, H.	1934		22-292			37.3	Calculated composition (49.9 a/o Cu); annealed.
31	128	Grüneisen, E. and Reddemann, H.	1934		83-293			42.2	Calculated composition (55 a/o Cu); annealed.
32	128	Grüneisen, E. and Reddemann, H.	1934		22-292			42.2	The above specimen reannealed in vacuum at about 850 C for 2 h.
33	128	Grüneisen, E. and Reddemann, H.	1934		22-273			42.2	The above specimen reannealed at about 325 C for 30 h.
34	223	Pott, F.P.	1958		308-863		52.75	97.25	Calculated composition (40 a/o Pd); cut from a 0.2 mm thick sheet, cold-rolled; annealed at 650 C for 2 h; ordered.
35	223	Pott, F.P.	1958		273-833		57.81	42.19	Calculated composition (45 a/o Pd); similar to the above specimen.
36	223	Pott, F.P.	1958		273-853		70.67	29.33	Calculated composition (59 a/o Pd); similar to the above specimen.
37	223	Pott, F.P.	1958		298-1065		52.75	47.25	Calculated composition (40 a/o Pd); similar to the above specimen but disordered.
38	223	Pott, F.P.	1958		309-1073		57.81	42.19	Calculated composition (45 a/o Pd); similar to the above specimen.
39	223	Pott, F.P.	1958		305-1073		70.67	29.33	Calculated composition (59 a/o Pd); similar to the above specimen.

* Not shown in figure.

TABLE 33. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + COPPER ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

T	ρ
DATA SET 1	
23	35.4
42	36.1
50	36.5
60	36.8
72	37.5
81	37.9
100	38.5
119	39.2
135	39.6
160	40.2
182	40.6
194	40.8
204	41.0
221	41.4
229	41.5*
247	41.7
261	41.8*
278	42.1
304	42.3
DATA SET 2	
22	25.0
30	25.0
39	25.1
49	25.3
62	25.5
77	25.8
94	26.3
115	26.7
143	27.4
161	27.7
182	28.3
210	28.8
233	29.4
259	29.9
285	30.6
DATA SET 3	
87	27.2
138	27.7
163	27.8*
232	28.7
303	29.5
DATA SET 3 (cont.)	
379	30.4
494	31.4
541	9.5
571	8.7
661	9.4
742	10.5
796	11.6
828	12.4
890	35.0
926	35.8
959	36.5
DATA SET 4	
82	3.8
120	4.3
157	4.5
191	4.8
236	5.2
299	5.9
398	6.9
512	7.9
561	8.4
627	9.1
721	10.3
753	10.6*
787	11.3
820	12.2
842	13.3
870	26.4
879	34.6*
944	35.7*
980	36.3
DATA SET 5	
82	3.18
112	3.59
157	3.86
190	4.21
228	4.48
292	5.17
406	6.23
533	7.39
642	8.40
DATA SET 5 (cont.)	
722	9.52
749	10.33*
780	10.70
814	11.54
839	12.46
871	36.27
918	37.34
951	37.91
DATA SET 6	
85	30.18
127	31.28
190	33.19
241	34.55
300	36.08
375	37.95
475	40.00
578	41.72
708	43.78
805	45.04
917	46.37
DATA SET 7	
293	8.3
385	9.4
405	9.6
505	10.9
534	11.3
599	12.0
648	12.9
663	12.9
721	14.0
731	14.0
744	14.6*
756	14.8
767	14.9*
781	15.3
790	15.7
804	15.9
818	16.4*
830	16.6
839	16.8
847	17.1
DATA SET 7 (cont.)	
857	17.4*
867	17.8*
877	18.1*
886	18.5*
892	19.0*
899	19.1
912	19.8
916	20.3*
920	22.0
924	25.5*
929	32.0*
933	36.0*
937	36.8
940	38.7
943	39.8*
947	40.5
DATA SET 8	
834	17.4
856	18.6*
859	19.0*
867	19.6*
868	25.6*
869	30.4*
872	37.9
875	39.6*
884	39.7*
888	40.1
893	39.9*
896	40.3*
899	38.9
899	39.6
909	39.8
917	40.0
921	39.8
932	40.5*
935	40.3
942	40.5
DATA SET 9	
297	5.8
573	8.4
630	9.3
DATA SET 9 (cont.)	
677	9.9*
687	10.1
711	10.6
738	11.1*
775	11.9*
784	12.0
815	12.7
851	13.8*
866	14.3
880	14.7*
885	15.0
892	15.3*
898	17.7*
898	19.1*
900	21.2
902	23.7*
906	26.3
907	31.8*
909	34.3*
910	36.0*
912	37.4*
916	38.0*
926	38.6*
DATA SET 10	
293	5.5
573	8.4*
630	9.3*
677	9.9*
687	10.1*
710	10.6*
738	11.1*
775	11.9*
784	12.0*
793	12.4
799	12.7
810	13.2
813	13.9*
817	15.8*
820	17.3*
822	19.7
823	22.6
826	25.4*
829	29.2*
DATA SET 10 (cont.)	
835	32.6
840	33.7*
843	34.4
845	34.7*
847	35.4
851	35.7
854	36.6*
858	37.1*
865	37.4*
874	37.8*
879	37.8*
886	38.0*
895	38.0*
904	38.1*
910	38.2*
926	38.6*
DATA SET 11	
292	29.9
494	31.0
683	26.9
705	21.2
728	19.7
750	19.4
766	19.5
774	19.5
786	19.6
795	19.6*
806	19.8
814	20.1*
830	20.3
838	20.5*
848	20.8*
858	21.2*
868	21.8*
873	22.2
878	22.8*
886	24.2
889	24.7*
890	25.5*
890	26.3*
892	27.1
894	28.3*
894	29.5*

* Not shown in figure.

TABLE 33. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + COPPER ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 11 (cont.)	
896	30.3*
896	30.7
897	31.2
DATA SET 12*	
859	33.4
880	33.5
891	33.5
901	33.5
906	33.5
DATA SET 13	
748	16.1
767	23.7*
777	27.7*
780	28.6
796	31.3
801	32.0*
805	32.3*
815	32.6*
823	33.0
835	33.3
857	33.4*
880	33.6*
889	33.7*
900	33.7
909	33.9*
921	34.0*
934	34.2*
941	34.2*
952	34.2*
DATA SET 14*	
748	16.1
764	16.5
780	17.2
820	16.8
848	17.5
859	17.7
869	18.0
879	18.4
889	19.6
898	22.5
900	30.4
903	31.2

T	ρ
DATA SET 14 (cont.)*	
907	31.9
913	32.6
921	32.8
926	32.6
936	32.6
942	32.8
DATA SET 15	
291	11.3*
369	12.3
515	13.8
671	15.6*
692	15.8
773	24.2*
778	25.9*
784	28.2
807	31.7
819	32.1
831	32.3*
852	32.4
863	32.4*
875	32.5*
921	32.8*
926	32.6
936	32.6*
942	32.8*
DATA SET 16	
291.2	33.11
DATA SET 17	
291.2	38.90
DATA SET 18*	
291.2	36.68
DATA SET 19*	
291.2	35.82
DATA SET 20*	
291.2	5.54

T	ρ
DATA SET 21	
293.2	5.44*
298.2	5.51*
323.2	5.63
348.2	5.83
373.2	6.00
398.2	6.23*
423.2	6.50
448.2	6.72*
473.2	6.99
498.2	7.30
523.2	7.57*
548.2	7.84
573.2	8.11
598.2	8.48
623.2	8.74*
648.2	9.03*
673.2	9.33
698.2	9.74
723.2	10.22*
748.2	10.62*
773.2	11.00*
798.2	11.51*
823.2	11.99
848.2	12.47*
873.2	32.65*
898.2	32.96*
DATA SET 22	
293.2	8.59*
298.2	8.71
323.2	9.13
348.2	9.53*
373.2	9.93
398.2	10.31*
423.2	10.71
448.2	11.12*
473.2	11.50
498.2	11.97*
523.2	12.44
548.2	12.83*
573.2	13.24
598.2	13.58*
623.2	14.05*
648.2	14.59
673.2	15.32*
698.2	16.47
723.2	17.69*

T	ρ
DATA SET 22 (cont.)	
748.3	19.60
773.2	23.98
798.2	31.81
823.2	40.09*
848.2	40.79
873.2	40.92
DATA SET 23	
293.2	28.18*
298.2	28.34
323.2	28.60
348.2	28.82*
373.2	29.22
398.2	29.62*
423.2	30.03
448.2	30.36*
473.2	30.84*
498.2	31.24*
523.2	31.74
548.2	32.18*
573.2	32.55
598.2	33.09*
623.2	33.53
648.2	34.00*
673.2	34.89
698.2	36.01*
723.2	37.34
748.2	38.73*
773.2	40.39
798.2	40.58*
823.2	40.72
848.2	40.79*
873.2	40.92
898.2	41.11
DATA SET 24	
293	6.9
873	31.4
DATA SET 25*	
293	4.9
873	31.4

T	ρ
DATA SET 26*	
293	3.9
873	36.5
DATA SET 27*	
293	14.5
873	41.4
DATA SET 28	
873	45.0
DATA SET 29	
22	20.59
83	22.18
273	28.05
DATA SET 30	
22	32.49
83	33.68
273	36.80
291.60	37.15
DATA SET 31	
83	3.168
273	5.10
292.6	5.32
DATA SET 32	
22	33.47
83	34.01
273	36.40
291.60	36.60
DATA SET 33	
22	2.812
83	3.286
273	5.25
DATA SET 34	
308	7.8
573	10.8
863	14.9

T	ρ
DATA SET 35	
273	4.3
564	7.7
833	11.0
DATA SET 36	
273	49.3
587	50.6
853	51.4
DATA SET 37	
298	28.4
673	31.4
1065	35.9
DATA SET 38	
309	34.2
673	37.4
1073	41.4
DATA SET 39	
305	47.6
673	49.7
1073	51.7

* Not shown in figure.

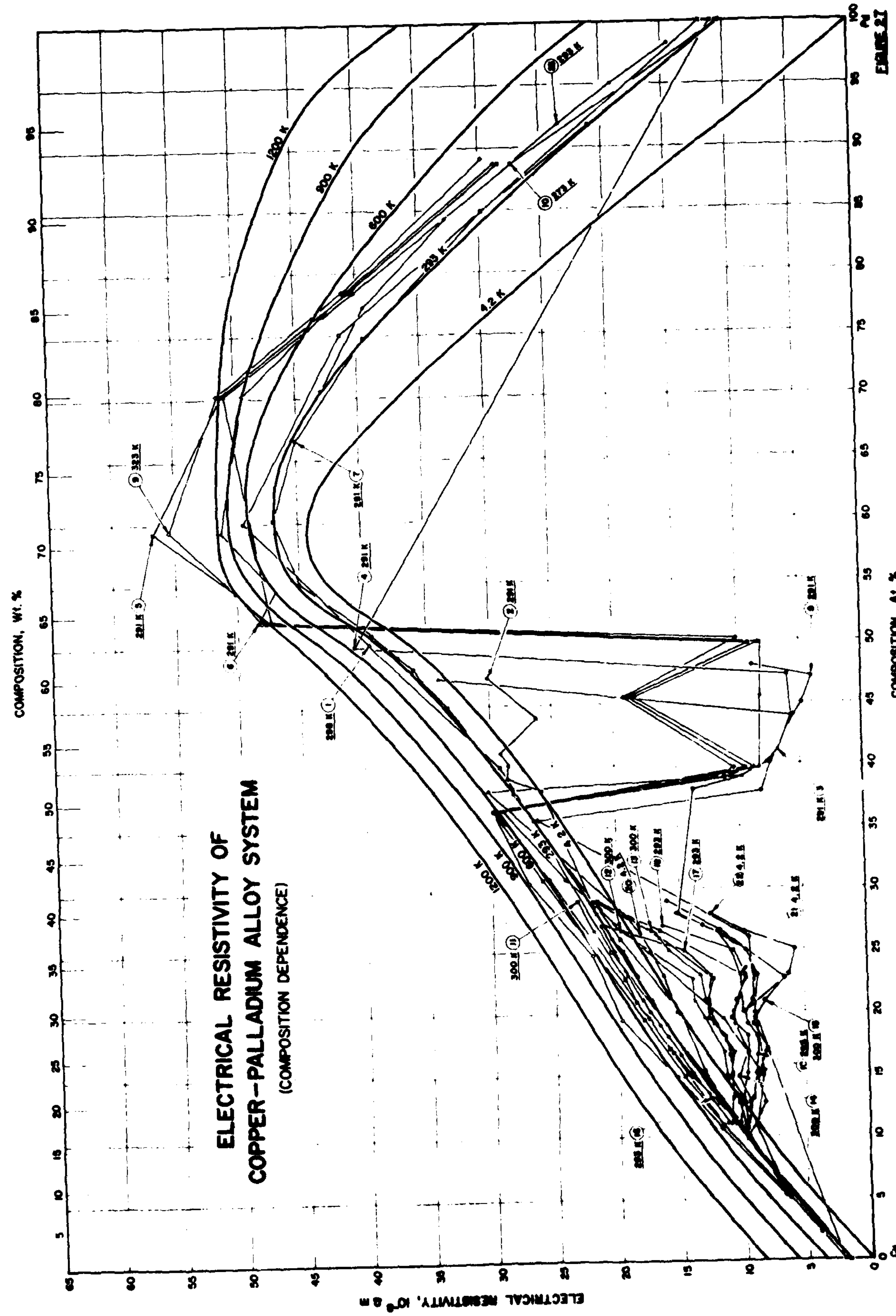

ELECTRICAL RESISTIVITY OF
COPPER–PALLADIUM ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION, Wt. %
COMPOSITION, At. %
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
1200 K
900 K
600 K
293 K
4.2 K
Cu
Pd
CINDAS

FIGURE 27

TABLE 34. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM (Composition Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Pd)	Composition (weight percent), Specifications, and Remarks
1	232	Kim, M.J. and Flanagan, W.F.	1967		298.2	0-100	Alloys prepared by induction melting mixtures of 99.97 pure palladium from Engelhard Industries, Inc. and 99.999 pure copper from American Smelting and Refining Co. in a vacuum of 10^{-5} to 10^{-6} torr; homogenized at 1173 K for one week in vacuum, grounded; heat-treated at 973 K for 2 days.
2	222	Johansson, C.H. and Linde, J.O.	1927		291.2	17-47	Specimens quenched and hard-worked.
3	222	Johansson, C.H. and Linde, J.O.	1927		291.2	17-47	The above specimens annealed at below melting point for 2 to 3 h.
4	222	Johansson, C.H. and Linde, J.O.	1927		291.2	0-100	The above specimens tempered.
5	222	Johansson, C.H. and Linde, J.O.	1927		291.2	5.4-89	Data of Sedström (Dissertation, Stockholm, 1924) reported by the authors.
6	222	Johansson, C.H. and Linde, J.O.	1927		291.2	2.1-89	The above specimens tempered.
7	221	Svensson, B.	1932	B	291.2	0-100	Alloys prepared from physically pure palladium supplied by Heraeus and technically pure copper; 40 x 1 x 1 mm; homogenized at 1273 to 1323 K for 10 to 12 h.
8	221	Svensson, B.	1932	B	291.2	11-48	The above specimens heated to 973 K and cooled slowly to 773 K; ordered.
9	234	Holgersson, S. and Sedström, E.	1924		323.2	5.2-89	No details reported.
10	235	Sedström, E.	1924		273.2	0-100	Data taken from Schulze, A. (Z. Anorg. Chem., 159, 325-42, 1927).
11	225	Jaumot, F.E., Jr. and Sawatzky, A.	1956	A	300	6.4-29	99.99⁺ pure copper from Vacuum Metals Co. and 99.99⁺ pure palladium from J. Bishop Co. melted together in vacuum, forged and swaged, annealed in vacuum at 1073 K for 2 h and quenched; reported error ± 2%.
12	225	Jaumot, F.E., Jr. and Sawatzky, A.	1956	A	300	6.4-29	Similar to the above specimens but furnace-cooled from 1073 K.
13	225	Jaumot, F.E., Jr. and Sawatzky, A.	1956	A	300	6.4-29	Similar to the above specimens but reannealed at 673 K for 24 h and quenched.
14	225	Jaumot, F.E., Jr. and Sawatzky, A.	1956	A	300	6.4-29	Similar to the above specimens but cooled from 1073 K at a rate 2 $K day^{-1}$ to 673 K and quenched.
15	225	Jaumot, F.E., Jr. and Sawatzky, A.	1956	A	300	6.4-29	Similar to the above specimens but cooled from 1073 K at a rate 2 $K day^{-1}$ to 528 K and quenched.
16	224	Köster, W. and Lang, W.	1958		293.2	11-27	High purity Cu and Pd mixed and melted in argon atmosphere, cast, cold-hammered to 3 to 4 mm in diameter with annealing at 973 K and subsequent quenching between hammerings; quenched from 783 K; measuring temperature not given, assigned here as 20 C.
17	224	Köster, W. and Lang, W.	1958		293.2	11-27	The above specimens annealed at 693 K for 5 days.
18	224	Köster, W. and Lang, W.	1958		293.2	11-27	The above specimens reannealed at 633 K for 2 days.
19	224	Köster, W. and Lang, W.	1958		293.2	11-27	The above specimens reannealed at 573 K for 2 days.
20	233	Buynova, L.N., Syutkina, V.I., Shashkov, O.D., and Yakovleva, E.S.	1972	A	4.2	20-28	99.99 pure copper and 99.98 pure palladium vacuum-melted, cast, and drawn into wires; quenched in water from 913 K.
21	233	Buynova, L.N., et al.	1972	A	4.2	20-28	Similar to the above specimens but heat-treated by cooling from 733 to 573 K at a rate of 100 K day^{-1}.
22	233	Buynova, L.N., et al.	1972	A	4.2	20-28	Similar to the above specimens but cooled at 2 K day^{-1}.
23	236	Mallory Metallurgical Co.	1964		293.2	70-96	Measuring temperature not given, assigned here as 20 C.

TABLE 35. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM (Composition Dependence)

[Composition, C, a/o Pd; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

DATA SET 1 (T = 298.2 K)

C	ρ
0	2.2
5	6.5
10	9.8
25	20.5
40	29.2
50	39.5
60	49.4
75	41.3
100	11.8

DATA SET 2 (T = 291.2 K)

C	ρ
17.0	14.9
19.0	16.2
21.0	17.4
23.0	18.5
25.0	19.6
26.0	20.4
28.0	21.6
38.0	25.9
39.0	28.6
40.1	28.5
41.1	29.1
43.9	26.2
47.2	30.1

DATA SET 3 (T = 291.2 K)

C	ρ
17.0	11.2
19.0	12.2
21.0	13.0
23.0	13.4
25.0	15.9
26.0	16.6
29.0	19.5
38.0	30.2
39.0	9.7
40.1	7.7
41.1	6.8
43.9	5.6
47.2	34.0

DATA SET 4 (T = 291.2 K)

C	ρ
0	2.2
17.0	8.1
19.0	9.2
23.0	8.8
25.0	9.7
26.0	11.1
28.0	15.1
38.0	13.7
39.0	9.7
40.1	7.7
41.1	6.8
43.9	5.6
47.2	5.9
49.9	40.7
100	11.0

DATA SET 5 (T = 291.2 K)

C	ρ
5.4	6.9
10.8	11.8
14.8	14.8
19.4	18.0
30.8	25.9
36.4	29.8
39.7	9.4
45.5	18.7
49.8	9.0
51.9	47.7
54.4	50.1
59.3	56.7
70.2	51.0
78.4	40.6
88.7	28.4

DATA SET 6 (T = 291.2 K)

C	ρ
2.1	4.02
5.4	6.7
6.9	7.5
10.8	9.1
14.8	8.5
19.4	11.6
30.8	24.1

DATA SET 6 (cont.) (T = 291.2 K)

C	ρ
36.4	29.0
39.7	8.3
45.5	8.1
49.8	8.1
51.9	48.4
54.4	46.9
59.3	51.2
70.2	49.3
78.4	40.8
88.7	28.7

DATA SET 7 (T = 291.2 K)

C	ρ
0	1.7
11.0	10.7
15.2	13.2
19.9	15.0
26.0	19.8
35.6	26.5
37.8	28.1
44.9	33.3
47.0	35.4
48.0	36.0
49.0	37.3
50.8	39.3
55.0	45.0
60.2	47.0
66.6	45.1
74.7	39.5
84.9	29.8
91.8	21.0
100	10.6

DATA SET 8 (T = 291.2 K)

C	ρ
11.0	9.1
15.2	8.4
19.9	9.0
26.0	9.4
35.6	26.2
37.8	8.2
40.1	7.4
43.9	5.5

DATA SET 8 (cont.) (T = 291.2 K)

C	ρ
44.9	4.8
47.0	4.0
48.0	8.8

DATA SET 9 (T = 323.2 K)

C	ρ
5.2	6.8
10.6	11.9
14.7	15.4
19.4	18.8
24.7	22.0
30.5	27.0
36.4	29.8
38.9	11.9
39.7	10.3
45.5	19.1
50.2	10.0
51.9	48.1
54.4	50.1
59.4	55.4
70.2	51.4
78.4	41.1
89.1	29.7

DATA SET 10 (T = 273.2 K)

C	ρ
0	1.90
5.4	6.90
10.8	11.8
30.8	25.4
36.4	29.7
38.9	11.1
39.7	8.77
45.5	18.3
49.8	8.26
51.9	47.4
70.2	50.8
78.4	40.2
88.7	27.3
100	10.3

DATA SET 11 (T = 300 K)

C	ρ
6.4	7.33
9.7	9.82
12.6	12.07
14.7	14.14
16.7	15.65
17.0	16.00
19.5	17.59
20.9	18.59
22.7	19.50
26.6	21.87
29.0	23.15

DATA SET 12 (T = 300 K)

C	ρ
6.4	7.33
9.7	9.82
12.6	10.43
14.7	11.46
16.7	11.55
19.5	13.04
20.9	13.85
22.7	14.00
26.6	19.75
29.0	21.76

DATA SET 13 (T = 300 K)

C	ρ
6.4	7.33
9.7	9.82
12.6	10.00
14.7	11.14
16.7	10.80
19.5	12.73
20.9	12.91
22.7	12.36
26.6	17.26
29.0	21.98

DATA SET 14 (T = 300 K)

C	ρ
6.4	7.33
9.7	9.82

DATA SET 14 (cont.) (T = 300 K)

C	ρ
12.6	9.53
14.7	10.48
16.7	9.66
19.5	10.92
20.9	10.57
22.7	9.81
26.6	16.66
29.0	21.65

DATA SET 15 (T = 300 K)

C	ρ
6.4	7.33
9.7	9.82
12.6	8.37
14.7	8.97
16.7	8.22
17.0	8.13
19.5	9.00
20.9	8.28
22.7	6.62
26.6	11.78
29.0	16.00

DATA SET 16 (T = 293.2 K)

C	ρ
11	11.34
13	12.70
15	14.11
16.5	15.06
18	16.09
19	16.74
20	17.44
21	18.05
23	19.27
25	20.28
27	21.27

DATA SET 17 (T = 293.2 K)

C	ρ
11	11.04
13	10.95
15	10.95

TABLE 35. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER-PALLADIUM ALLOY SYSTEM (Composition Dependence) (continued)

C	ρ
DATA SET 17 (cont.) (T = 293.2 K)	
16.5	11.11
18	11.47
19	12.30
20	12.57
21	12.79
23	12.59
25	14.62
27	20.90
DATA SET 18 (T = 293.2 K)	
11	10.44
13	10.14
15	9.72
16.5	9.63
18	9.63
19	10.64
20	10.71
21	10.35
23	9.80
25	10.67
27	16.34
DATA SET 19 (T = 293.2 K)	
11	9.85
13	9.39
15	9.02
16.5	8.90
18	8.90
19	9.79
20	9.84
21	9.26
23	9.16
25	9.68
27	13.11
DATA SET 20 (T = 4.2 K)	
20	15.3
23	16.4
25	17.4
26.3	18.2
28	19.6

C	ρ
DATA SET 21 (T = 4.2 K)	
20	10.0
23	10.2
25	10.9
26.5	12.0
28	15.3
DATA SET 22 (T = 4.2 K)	
20	9.9
23	6.3
25	5.7
26.5	9.7
28	12.5
DATA SET 23 (T = 293.2 K)	
70.5	42.9
77.2	39.4
84.3	32.7
91.9	23.4
95.1	19.1
98.3	14.5

3.6. Copper-Zinc Alloy System

The copper-zinc alloy system does not constitute a continuous series of solid solutions. The maximum solid solubility of zinc in copper is 39.0 wt.% (38.3 at.%) at 727 K and the solubility decreases at higher and lower temperatures. At lower temperatures, the attainment of equilibrium becomes very slow and the solubility data are uncertain. Massalski and Kittl [237] analyzed the existing data and concluded that the boundary lies at about 34 at.% Zn at 473 K and it may lie at less than 30 at.% Zn at room temperature. Shinoda and Amano [238] reported a much greater reduction in solubility at room temperature. The maximum solid solubility of copper in zinc is 2.7 wt.% (2.77 at.%) at 697 K and it decreases to 0.3 wt.% (0.31 at.%) at 373 K.

There are 175 sets of experimental data available for this alloy system. These data sets are listed in tables 37, 39, and 41, tabulated in tables 38, 40, and 42, and shown partially in figures 29, 30, and 31. Most of the available data are for copper-rich alloys in the solid solution region. Due to the scarcity of data for zinc-rich alloys, the available data for Zn + Cu alloys are not evaluated and no recommendations are made in the present work.

For Cu + Zn alloys, Argent and Lee [239] (Cu + Zn data sets 31-50) reported the electrical resistivity for various compositions ranging from pure copper to 34.2 wt.% Zn at 77, 195, 273, and 373 K. Henry and Schroeder [240] (Cu + Zn data sets 57-65) reported the electrical resistivity of alloys with compositions ranging from 0.93 to 35.97 wt.% Zn at temperatures below room temperature. The values of Argent and Lee scatter more than those of Henry and Schroeder on a plot of resistivity versus composition.

Fairbank [241] (Cu + Zn data sets 12-30) has investigated the electrical resistivity of a full range of alloy compositions in the alpha-phase solid solution region in the temperature range 14.3 K to room temperature. Measurements were made on both annealed and hard-drawn specimens. His values for the annealed specimens are higher than those reported by other authors.

The data outside the region of solid solution are fragmentary and conflicting. In addition, beta-brass (46-48 wt.% Zn) forms ordered structures below about 735 K. For these reasons the data smoothing and synthesis was limited to the alpha-phase solid solution and was based mainly on the results of Henry and

Schroeder, Smith [242] (Cu + Zn data sets 67-79), Smith and Palmer [64] (data set 80), and Kemp, Klemens, Tainsh, and White [129, 246, 247] (Cu + Zn data sets 81-94).

The resulting recommended electrical resistivity values for Cu, Zn, and for 9 Cu + Zn binary alloys are presented in table 36 and shown in figures 28 and 31. No values were generated for alloys containing 35 to 99.5% Zn. The recommended values for Cu and for Zn are for well-annealed high-purity specimens, but those values for temperatures below about 100 K are applicable only to Cu and Zn having residual electrical resistivities as given at 1 K in table 36. The alloys for which the recommended values are generated are not ordered and have not been quenched or cold-worked severely. The recommended values cover the temperature range from 1 K to 700 K. These values are not corrected for the thermal expansion of the material. The estimated uncertainties in the values for the various alloys and for different temperature ranges are explicitly stated in a footnote to table 36.

TABLE 36. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-ZINC ALLOY SYSTEM†

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Cu: 100.00% (100.00 At.%) Zn: 0.00% (0.00 At.%)		Cu: 99.50% (99.51 At.%) Zn: 0.50% (0.49 At.%)		Cu: 99.00% (99.03 At.%) Zn: 1.00% (0.97 At.%)		Cu: 97.00% (97.08 At.%) Zn: 3.00% (2.92 At.%)		Cu: 95.00% (95.13 At.%) Zn: 5.00% (4.87 At.%)		Cu: 90.00% (90.25 At.%) Zn: 10.00% (9.75 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	0.00200	1	0.150*	1	0.270	1	0.710	1	1.09	1	1.84
4	0.00200	4	0.150	4	0.270	4	0.710	4	1.09	4	1.84
7	0.00200	7	0.150	7	0.270	7	0.710	7	1.09	7	1.84
10	0.00202	10	0.150	10	0.270	10	0.710	10	1.09	10	1.84
15	0.00218	15	0.150	15	0.271	15	0.710	15	1.09	15	1.85
20	0.00280	20	0.151	20	0.279	20	0.710	20	1.10	20	1.86
25	0.00450	25	0.159	25	0.289	25	0.711	25	1.11	25	1.87
30	0.00830	30	0.172	30	0.302	30	0.719	30	1.13	30	1.88
40	0.0240	40	0.207	40	0.338	40	0.748	40	1.16	40	1.91
50	0.0320	50	0.243	50	0.381	50	0.794	50	1.20	50	1.96
60	0.0974	60	0.288	60	0.431	60	0.856	60	1.26	60	2.02
70	0.154	70	0.341	70	0.489	70	0.924	70	1.33	70	2.10
80	0.216	80	0.397	80	0.550	80	0.996	80	1.40	80	2.18
90	0.282	90	0.452	90	0.610	90	1.06	90	1.47	90	2.26
100	0.349	100	0.511	100	0.671	100	1.13	100	1.54	100	2.33
150	0.701	150	0.846	150	0.999	150	1.48	150	1.90	150	2.72
200	1.048	200	1.19	200	1.34	200	1.83	200	2.26	200	3.10
250	1.388	250	1.53	250	1.68	250	2.18	250	2.61	250	3.48
273	1.544	273	1.69	273	1.84	273	2.34	273	2.78	273	3.66
293	1.678	293	1.82	293	1.97	293	2.48	293	2.92	293	3.81
300	1.725	300	1.87	300	2.02	300	2.53	300	2.97	300	3.86
350	2.061	350	2.22	350	2.36	350	2.88	350	3.33	350	4.25
400	2.398	400	2.56	400	2.71	400	3.23	400	3.69	400	4.63
500	3.079	500	3.25*	500	3.40*	500	3.93*	500	4.41*	500	5.40*
600	3.771	600	3.94*	600	4.09*	600	4.63*	600	5.13*	600	6.17*
700	4.481	700	4.63*	700	4.78*	700	5.33*	700	5.85*	700	6.94*
800	5.213										
900	5.973										
1000	6.766										
1100	7.596										
1200	8.470										
1300	9.395										
1357.6	9.946(s)										
1358	21.01(ℓ)										
1700	24.41										

† Uncertainties in the electrical resistivity values are as follows:

100.00 Cu - 0.00 Zn: ±3% up to 100K, ±1% above 100K to 250K, ±0.5% above 250K to 350K, ±1% above 350K to 500K, ±4% above 500K to 1357.6K, and ±5% above 1357.6K.
99.50 Cu - 0.50 Zn: ±3% below 500 K and ±5% from 500 to 700 K.
99.00 Cu - 1.00 Zn: ±3% below 500 K and ±5% from 500 to 700 K.
97.00 Cu - 3.00 Zn: ±3% below 500 K and ±5% from 500 to 700 K.
95.00 Cu - 5.00 Zn: ±3% below 500 K and ±5% from 500 to 700 K.
90.00 Cu - 10.00 Zn: ±3% below 500 K and ±5% from 500 to 700 K.

* In temperature range where no experimental data are available.

TABLE 36. RECOMMENDED ELECTRICAL RESISTIVITY OF COPPER-ZINC ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Cu: 85.00% (85.36 At.%) Zn: 15.00% (14.64 At.%)		Cu: 80.00% (80.45 At.%) Zn: 20.00% (19.55 At.%)		Cu: 75.00% (75.53 At.%) Zn: 25.00% (24.47 At.%)		Cu: 70.00% (70.59 At.%) Zn: 30.00% (29.41 At.%)		Cu: 0.00% (0.00 At.%) Zn: 100.00% (100.00 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	2.38	1	2.84	1	3.20*	1	3.39	1	0.0100*
4	2.38	4	2.84	4	3.20	4	3.39	4	0.0100
7	2.38	7	2.84	7	3.20	7	3.39	7	0.0102
10	2.38	10	2.84	10	3.20	10	3.39	10	0.0112
15	2.39	15	2.85	15	3.21	15	3.40	15	0.0190
20	2.40	20	2.86	20	3.22	20	3.41	20	0.0387
25	2.42	25	2.87	25	3.23	25	3.43	25	0.0788
30	2.44	30	2.89	30	3.24	30	3.46	30	0.142
40	2.48	40	2.93	40	3.30	40	3.51	40	0.306
50	2.54	50	3.00	50	3.36	50	3.58	50	0.507
60	2.60	60	3.08	60	3.44	60	3.68	60	0.715
70	2.68	70	3.17	70	3.54	70	3.78	70	0.931
80	2.77	80	3.26	80	3.64	80	3.88	80	1.15
90	2.85	90	3.35	90	3.74	90	3.98	90	1.37
100	2.93	100	3.44	100	3.83	100	4.08	100	1.60
150	3.35	150	3.89	150	4.32	150	4.60	150	2.71
200	3.77	200	4.35	200	4.81	200	5.12	200	3.83
250	4.18	250	4.80	250	5.29	250	5.63	250	4.95
273	4.37	273	5.01	273	5.52	273	5.87	273	5.46
293	4.54	293	5.19	293	5.71	293	6.08	293	5.90
300	4.60	300	5.26	300	5.78	300	6.15	300	6.06
350	5.02	350	5.71	350	6.27	350	6.67	350	7.20
400	5.44	400	6.17	400	6.76	400	7.19	400	8.37
500	6.29*	500	7.08*	500	7.74*	500	8.23*	500	10.82
600	7.12*	600	7.99*	600	8.72*	600	9.27*	600	13.49
700	7.95*	700	8.90*	700	9.70*	700	10.31*	692.73	16.23*

† Uncertainties in the electrical resistivity values are as follows:

85.00 Cu - 15.00 Zn: ±3% below 500 K and ±5% from 500 to 700 K.
80.00 Cu - 20.00 Zn: ±3% below 500 K and ±5% from 500 to 700 K.
75.00 Cu - 25.00 Zn: ±3% below 500 K and ±5% from 500 to 700 K.
70.00 Cu - 30.00 Zn: ±3% below 500 K and ±5% from 500 to 700 K.
0.00 Cu - 100.00 Zn: ±5% below 50 K, ±3% from 50 to 400 K, and ±4% above 400 K.

* In temperature range where no experimental data are available.

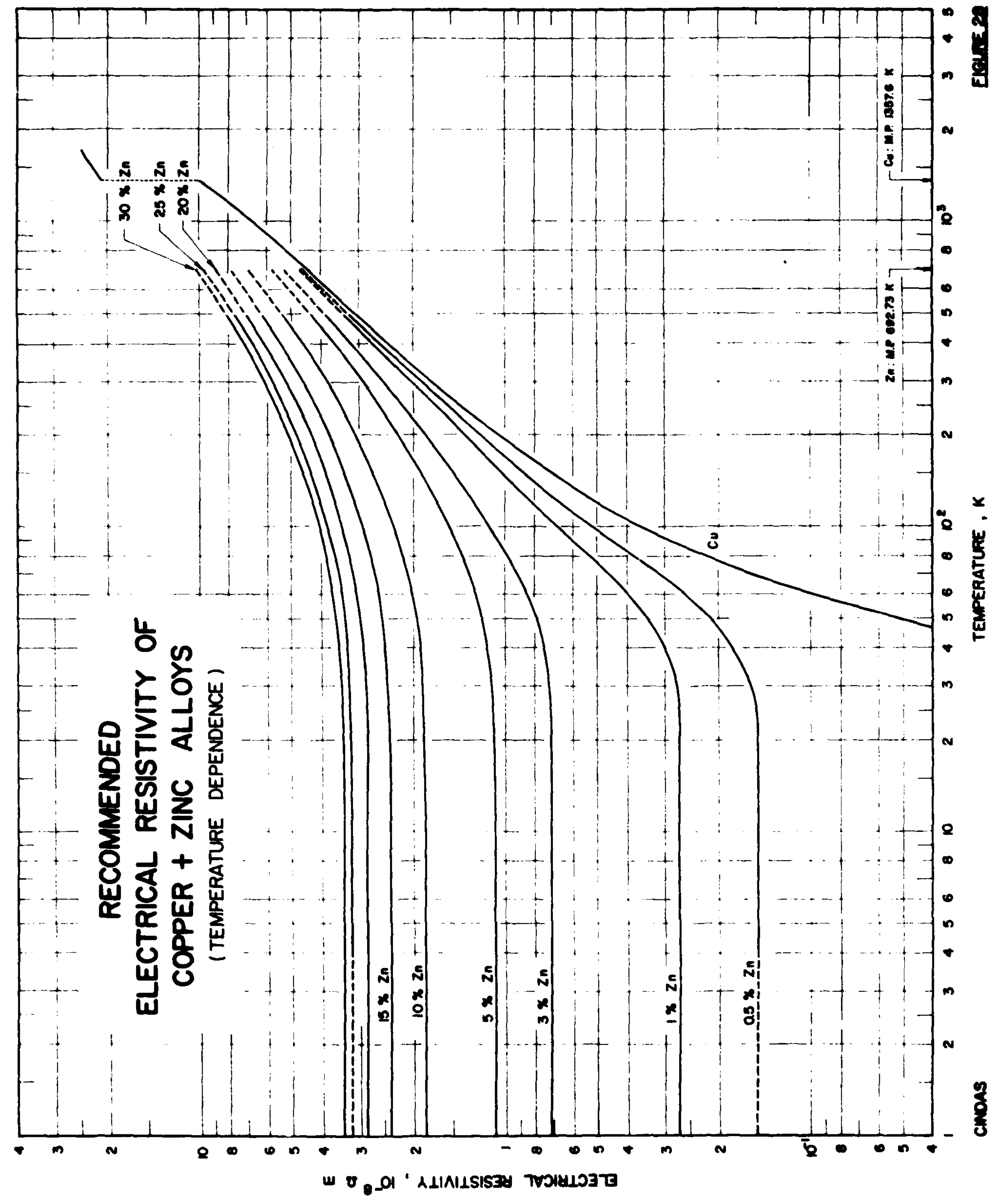

RECOMMENDED
ELECTRICAL RESISTIVITY OF
COPPER + ZINC ALLOYS
(TEMPERATURE DEPENDENCE)
30 % Zn
25 % Zn
20 % Zn
15 % Zn
10 % Zn
5 % Zn
3 % Zn
1 % Zn
0.5 % Zn
Cu
Zn: M.P. 692.73 K
Cu: M.P. 1357.6 K
TEMPERATURE, K
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
CINDAS

FIGURE 28

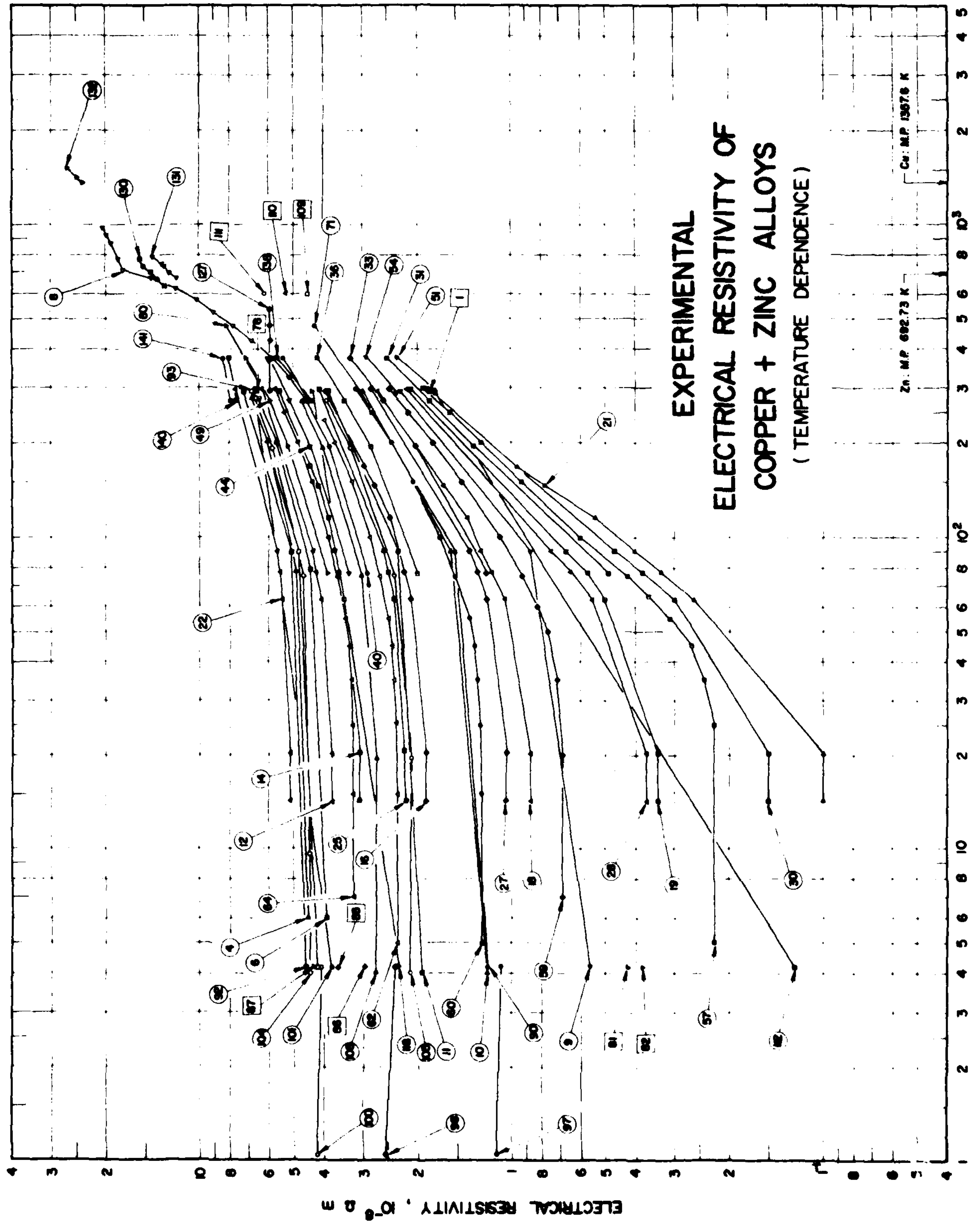
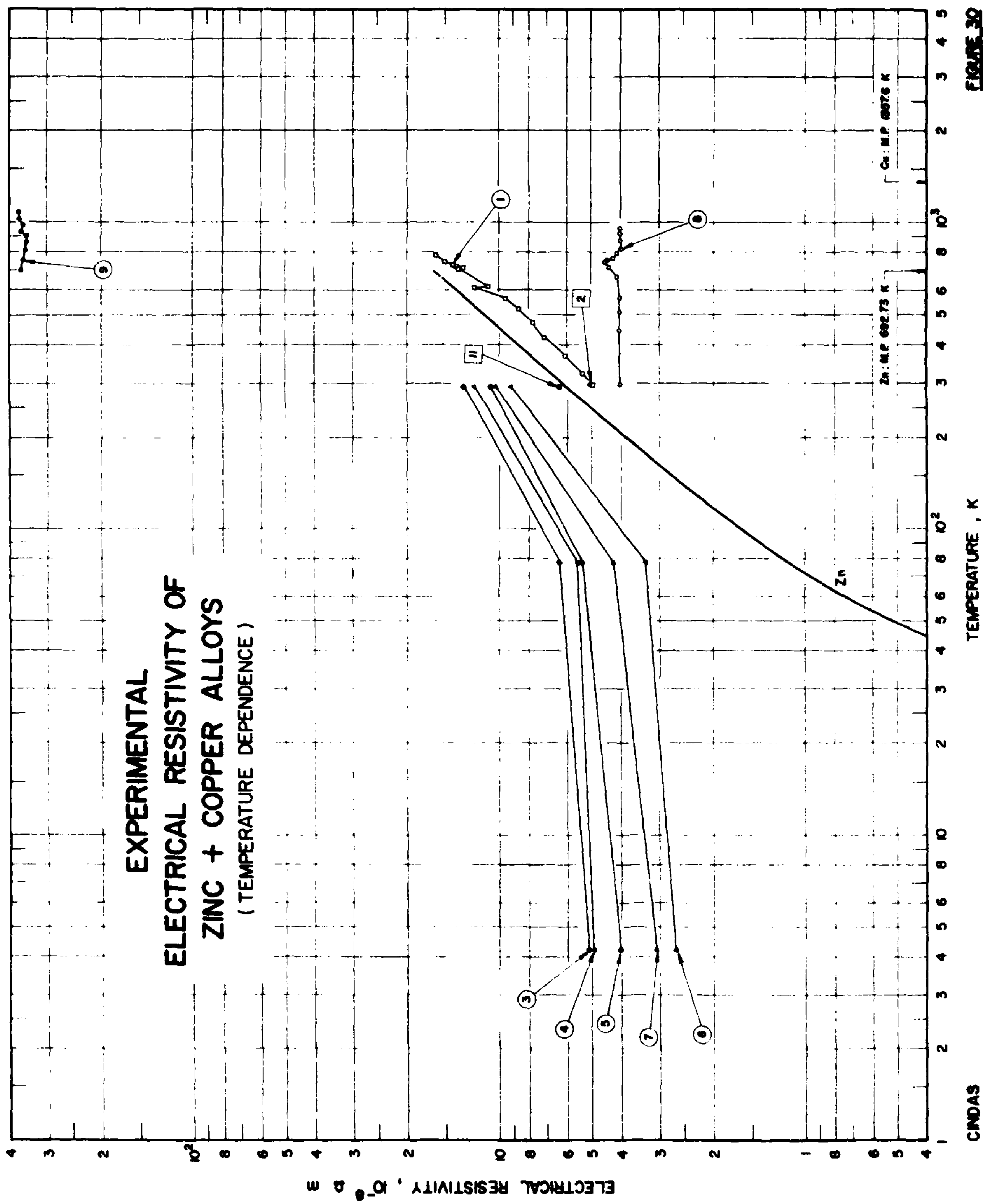

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
COPPER + ZINC ALLOYS
(TEMPERATURE DEPENDENCE)
Cu: M.P. 1357.6 K
Zn: M.P. 692.73 K
TEMPERATURE , K
ELECTRICAL RESISTIVITY , 10^{-8} Ω m
CINDAS

FIGURE 29



CINDAS

FIGURE 30

TABLE 37. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Zn	Composition (continued), Specifications, and Remarks
1	126	Linde, J.O.	1932		291			0.542	Calculated composition (0.527 a/o Zn).
2*	126	Linde, J.O.	1932		291			0.841	Calculated composition (0.818 a/o Zn).
3*	126	Linde, J.O.	1932		291			1.77	Calculated composition (1.724 a/o Zn).
4	41	Damask, A.C.	1956	A	6.0-279	α-brass		29.5	Wire specimen about 3 in. long and 0.015 in. in diameter; cold worked, annealed at 350 C, then drawn at room temperature to 60% reduction in area; annealed at 350 C for 1 hr, quenched in room temperature air stream to 50-60 C, then removed from air stream and allowed to cool to room temperature.
5*	41	Damask, A.C.	1956	A	6.0-277	α-brass		29.5	Similar to the above specimen except annealed for 30 min at 211 C after cold work.
6	41	Damask, A.C.	1956	A	6.0-278	α-brass		29.5	Similar to the above specimen except quenched from 320 C after completely annealed.
7*	41	Damask, A.C.	1956	A	5.0-278	α-brass		29.5	Similar to the above specimen except additionally annealed for 30 min at 211 C after completely annealed and quenched.
8	243	Takano, K.	1969	A	273-973			49.01	Calculated composition (48.3 a/o Zn); 20 x 5 x 0.1 mm; cut from ingots prepared by vacuum melting of high purity copper and zinc; heat-treated at appropriate temperature for two weeks.
9	244	Tainsh, R.J. and White, G.K.	1962		4.2-293			2.06	Calculated composition (2.0 a/o Zn); rod specimen 6 cm long and 3 to 5 mm in diameter; annealed at 850 C.
10	244	Tainsh, R.J. and White, G.K.	1962		4.2-293			5.14	Calculated composition (5.0 a/o Zn); similar to the above specimen.
11	244	Tainsh, R.J. and White, G.K.	1962		4.2-293			10.26	Calculated composition (10.0 a/o Zn); similar to the above specimen.
12	241	Fairbank, H.A.	1944	A	14-296			33.79	Alloy supplied by the American Brass Company of Waterbury, Connecticut; 0.04 in. diameter x 3 in. long; 0.75 in. rod hot-rolled flat to a strip 0.200 in. thick at 800 C, square rod 0.2 in. x 0.2 in. sawed out, swaged round, and drawn in round dies to 0.04 in. diameter, annealed at 700 C for one hour in a graphite mold and then rapidly quenched in cold water.
13*	241	Fairbank, H.A.	1944	A	14-293			29.39	Similar to the above specimen.
14	241	Fairbank, H.A.	1944	A	14-293			19.59	Similar to the above specimen.
15*	241	Fairbank, H.A.	1944	A	14-293			15.61	Similar to the above specimen.
16	241	Fairbank, H.A.	1944	A	14-293			9.66	Similar to the above specimen.
17*	241	Fairbank, H.A.	1944	A	14-293			4.65	Similar to the above specimen.
18	241	Fairbank, H.A.	1944	A	14-293			3.06	Similar to the above specimen.
19	241	Fairbank, H.A.	1944	A	14-296			0.93	Similar to the above specimen.
20*	241	Fairbank, H.A.	1944	A	14-293			0.50	Similar to the above specimen.
21	241	Fairbank, H.A.	1944	A	14-293			0.34	Similar to the above specimen.

* Not shown in figure.

TABLE 37. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Composition (weight percent) Zn	Composition (continued), Specifications, and Remarks
22	241	Fairbank, H.A.	1944	A	14-297			29.39	Alloy furnished by the American Brass Company of Waterbury, Connecticut; 0.04 in. diameter x 3 in. long; 0.75 in. rod hot-rolled flat to a strip 0.200 in. thick at 800 C, square rod 0.2 in. x 0.2 in. sawed out, swaged round, and drawn in round dies to 0.04 in. diameter.
23*	241	Fairbank, H.A.	1944	A	14-297			19.59	Similar to the above specimen.
24*	241	Fairbank, H.A.	1944	A	14-293			15.61	Similar to the above specimen.
25	241	Fairbank, H.A.	1944	A	14-297			9.66	Similar to the above specimen.
26*	241	Fairbank, H.A.	1944	A	14-297			4.65	Similar to the above specimen.
27	241	Fairbank, H.A.	1944	A	14-297			3.06	Similar to the above specimen.
28	241	Fairbank, H.A.	1944	A	14-297			0.93	Similar to the above specimen.
29*	241	Fairbank, H.A.	1944	A	14-296			0.50	Similar to the above specimen.
30	241	Fairbank, H.A.	1944	A	14-297			0.34	Similar to the above specimen.
31	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			1.03	Calculated composition (1 a/o Zn); wire specimen 0.039 in. in diameter; prepared from 99.99⁺ pure elements by melting, homogenizing at >1023 K for one week, then rolling and drawing; annealed at 400 C, then annealed at same temperature for one hour to give a grain size of 0.027 mm, and finally annealed at 400 C for 1 hr, cooled rapidly to room temperature.
32*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			2.06	Calculated composition (2 a/o Zn); similar to the above specimen.
33	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			4.11	Calculated composition (4 a/o Zn); similar to the above specimen.
34*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			6.16	Calculated composition (6 a/o Zn); similar to the above specimen.
35*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			7.19	Calculated composition (7 a/o Zn); similar to the above specimen.
36	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			8.21	Calculated composition (8 a/o Zn); similar to the above specimen.
37*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			10.26	Calculated composition (10 a/o Zn); similar to the above specimen.
38*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			12.30	Calculated composition (12 a/o Zn); similar to the above specimen.
39*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			14.35	Calculated composition (14 a/o Zn); similar to the above specimen.
40	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			16.39	Calculated composition (16 a/o Zn); similar to the above specimen.
41*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			17.40	Calculated composition (17 a/o Zn); similar to the above specimen.

* Not shown in figure.

TABLE 37. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Composition (weight percent) Zn	Composition (continued), Specifications, and Remarks
42*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			18.42	Calculated composition (18 a/o Zn); similar to the above specimen.
43*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			20.46	Calculated composition (20 a/o Zn); similar to the above specimen.
44	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			22.49	Calculated composition (22 a/o Zn); similar to the above specimen.
45*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			24.52	Calculated composition (24 a/o Zn); similar to the above specimen.
46*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			26.55	Calculated composition (26 a/o Zn); similar to the above specimen.
47*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			28.58	Calculated composition (28 a/o Zn); similar to the above specimen.
48*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			30.60	Calculated composition (30 a/o Zn); similar to the above specimen.
49	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			32.62	Calculated composition (32 a/o Zn); similar to the above specimen.
50*	239	Argent, B.B. and Lee, K.T.	1964	A	77-373			34.14	Calculated composition (33.5 a/o Zn); similar to the above specimen.
51	245	Crisp, R.S. and Henry, W.G.	1964	A	290, 375			0.48	Calculated composition (0.47 a/o Zn).
52*	245	Crisp, R.S. and Henry, W.G.	1964	A	290, 375			1.01	Calculated composition (0.98 a/o Zn).
53*	245	Crisp, R.S. and Henry, W.G.	1964	A	290, 375			1.39	Calculated composition (1.35 a/o Zn).
54	245	Crisp, R.S. and Henry, W.G.	1964	A	290, 375			2.43	Calculated composition (2.36 a/o Zn).
55*	245	Crisp, R.S. and Henry, W.G.	1964	A	290, 375			4.62	Calculated composition (4.50 a/o Zn).
56*	245	Crisp, R.S. and Henry, W.G.	1964	A	290, 375			6.92	Calculated composition (6.74 a/o Zn).
57	240	Henry, W.G. and Schroeder, P.A.	1963	A	5-298			0.93	Calculated composition (0.90 a/o Zn); American Smelting and Refining Co. copper (ρ(293 K)/ρ(4.2 K) = 1320) and consolidated Mining and Smelting Co.; 99.999 pure zinc; prepared by melting in alumina crucibles and chill-cast at least twice under purified argon into billets approximately 9 x 30 mm, annealed in Pyrex at 575 C in one-third of an atmosphere of purified argon for 7 days to remove local inhomogeneities, drawn to 0.5 mm wires, degreased and given a light etch in 10% nitric acid, then annealed in pyrex in one-third of an atmosphere of purified argon for 7 days at 575 C and allowed to cool in the air.
58*	240	Henry, W.G. and Schroeder, P.A.	1963	A	7-297			2.43	Calculated composition (2.36 a/o Zn); similar to the above specimen.

* Not shown in figure.

TABLE 37. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Zn	Composition (continued), Specifications, and Remarks
59	240	Henry, W.G. and Schroeder, P.A.	1963	A	7-298			3.01	Calculated composition (2.93 a/o Zn); similar to the above specimen.
60	240	Henry, W.G. and Schroeder, P.A.	1963	A	5-298			5.98	Calculated composition (5.82 a/o Zn); similar to the above specimen.
61*	240	Henry, W.G. and Schroeder, P.A.	1963	A	7-297			10.48	Calculated composition (10.22 a/o Zn); similar to the above specimen.
62	240	Henry, W.G. and Schroeder, P.A.	1963	A	5-237			14.22	Calculated composition (13.88 a/o Zn); similar to the above specimen.
63*	240	Henry, W.G. and Schroeder, P.A.	1963	A	7-299			18.89	Calculated composition (18.46 a/o Zn); similar to the above specimen.
64	240	Henry, W.G. and Schroeder, P.A.	1963	A	7-296			25.98	Calculated composition (25.44 a/o Zn); similar to the above specimen.
65*	240	Henry, W.G. and Schroeder, P.A.	1963	A	4-237			35.97	Calculated composition (35.32 a/o Zn); similar to the above specimen.
66*	60	Hibbard, W.R., Jr.	1959		20-299			8.61	Calculated composition (8.39 a/o Zn); annealed at 445 C for 2 hr; grain size 0.0125 mm.
67*	242	Smith, C.S.	1930		293	90	99.64	0.35	0.02 Fe and 0.01 Pb; polycrystalline; grain size 0.070 mm; cylindrical specimen 13.25 in. long and 0.750 in. in diameter; annealed at 650 C for 1 hr and cooled in air.
68*	242	Smith, C.S.	1930		293	89	99.45	0.51	0.01 Fe and 0.01 Pb; similar to the above specimen, but grain size 0.110 mm.
69*	242	Smith, C.S.	1930		293	73	88.93	0.95	0.02 Fe; similar to the above specimen, but annealing temperature 700 C and grain size 0.120 mm.
70*	242	Smith, C.S.	1930		293, 473	12	96.94	3.04	0.02 Fe; similar to the above specimen but annealing time 0.75 hr and grain size 0.100 mm.
71	242	Smith, C.S.	1930		293, 473	13	95.21	4.77	Similar to the above specimen but grain size 0.085 mm.
72*	242	Smith, C.S.	1930		293	14	90.07	9.91	0.01 Fe and 0.01 Pb; similar to the above specimen but grain size 0.095 mm.
73*	242	Smith, C.S.	1930		293	15	83.20	16.76	0.03 Fe and 0.01 Pb; similar to the above specimen but grain size 0.125 mm.
74*	242	Smith, C.S.	1930		293	16	79.62	20.35	0.01 Fe and 0.02 Pb; similar to the above specimen but grain size 0.190 mm.
75*	242	Smith, C.S.	1930		293	22	59.20	40.75	0.02 Fe and 0.03 Pb; similar to the above specimen but grain size 0.070 mm.
76*	242	Smith, C.S.	1930		293	85	50.30	49.49	0.01 Fe and 0.04 Pb; similar to the above specimen but annealing time 2 hr and grain size 0.16 mm.
77*	242	Smith, C.S.	1930		293	18	69.14	30.81	0.03 Fe and 0.02 Pb; same structure and dimensions as the above specimen; grain size 0.075 mm; annealed at 650 C for 0.75 hr and cooled in air.
78	242	Smith, C.S.	1930		293	21	65.43	34.53	0.01 Fe and 0.03 Pb; similar to the above specimen but grain size 0.060 mm.

* Not shown in figure.

TABLE 37. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Zn	Composition (continued), Specifications, and Remarks
79*	242	Smith, C.S.	1930		293	88	54.96	45.02	0.01 Fe; similar to the above specimen but annealing time 2 hr and grain size 0.040 mm.
80	64	Smith, C.S. and Palmer, E.W.	1935	B	293, 473	19	66.24	33.72	0.03 Pb and 0.01 Fe; annealed at 650 C for 0.75 hr.
81	246	Kemp, W.R.G., Klemens, P.G., Tainsh, R.J., and White, G.K.	1957		4.2	25		1.63	~8 cm long and 0.5 cm in diameter; supplied by Johnson, Matthey and Co., Ltd.; as drawn.
82	246	Kemp, W.R.G., et al.	1957		4.2	2		1.63	The above specimen annealed at 500 C for 4 hr in He atmosphere.
83*	246	Kemp, W.R.G., et al.	1957		4.2	55		5.37	Same dimension and supplier as the above specimen; as drawn.
84*	246	Kemp, W.R.G., et al.	1957		4.2	5		5.37	The above specimen annealed at 500 C for 4 hr in a He atmosphere.
85*	246	Kemp, W.R.G., et al.	1957		4.2	10		9.98	Similar to the above specimen.
86	246	Kemp, W.R.G., et al.	1957		4.2	20		19.48	Similar to the above specimen.
87	246	Kemp, W.R.G., et al.	1957		4.2	30S		31.87	Same dimension and supplier as the above specimen.
88*	246	Kemp, W.R.G., et al.	1957		4.2	30		31.87	The above specimen annealed in a He atmosphere at 500 C for 4 hr.
89*	129	Kemp, W.R.G., Klemens, P.G., Tainsh, R.J., and White, G.K.	1957		4.2-293			2	8 cm long and 0.5 cm in diameter; drawn and annealed at 850 C for 4 hr.
90	129	Kemp, W.R.G., et al.	1957		4.2-293			5	Similar to the above specimen.
91*	129	Kemp, W.R.G., et al.	1957		4.2-293			10	Similar to the above specimen.
92	247	Kemp, W.R.G., Klemens, P.G., and Tainsh, R.J.	1959		4.2-293			32	α-brass; machined from an annealed and torsionally deformed bar.
93	247	Kemp, W.R.G., et al.	1959		4.2-293			32	Similar to the above specimen but heated up to 250 C at a rate of 6 C min^{-1}.
94*	247	Kemp, W.R.G., et al.	1959		4.2-293			32	Similar to the above specimen but heated up to 400 C at a rate of 6 C min^{-1}.
95*	248	Eucken, A. and Neumann, O.	1924		90, 273	Red Brass		18	Polycrystalline; grain size 0.006 cm^2.
96*	248	Eucken, A. and Neumann, O.	1924		90, 273	Red Brass		18	Polycrystalline; grain size 0.11 cm^2.
97	249	Olsen, T.	1960		1.1, 4.2	Z4	95.4	4.59	0.01 Pb; cylindrical specimen 10 cm long; machined; annealed for 21 hr at 540 C.
98	249	Olsen, T.	1960		1.1, 4.2	Z15	84.53	15.43	0.02 Fe and 0.02 Pb; cylindrical specimen 10 cm long; machined; annealed for 21 hr at 540 C.
99*	249	Olsen, T.	1960		1.1, 4.2	Z20	86.56	13.43	0.01 Fe; cylindrical specimen 10 cm long; machined, cold worked, and annealed at 500 C for 17 hr.

* Not shown in figure.

TABLE 37. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Composition (weight percent) Zn	Composition (continued), Specifications, and Remarks
100	249	Olsen, T.	1960		1.1, 4.2	Z30	69.95	30.02	0.02 Fe and 0.01 Pb; cylindrical specimen 10 cm long; machined and annealed at 540 C for 21 hr.
101	250	Gordon, J.E. and Amstutz, L.I.	1965		4.2, 298	CDA alloy No. 26	69.3 ±0.5	30.9 ±0.5	0.07 Si, 0.025 Pb, and < 0.01 each of Fe, Co, and Ni; strip specimen 0.0150 cm in cross section and 3.46 cm long; supplied by Chase Brass and Copper Company; cold-rolled cartridge brass of nominal grain size 0.025-0.050 mm.
102*	251	Srivastava, B.N., Chatterjee, S., and Sen, S.K.	1969		4.2			1.96	Prepared from spectrographically pure rods of copper and zinc; supplied by Johnson, Matthey and Co. Ltd., by scaling the metals in appropriate portion in evacuated quartz tube, heating to 1100 C, shaking thoroughly, cooling to 900 C and maintaining for five days, rolled, then annealed at 500 C for 6 hr.
103*	251	Srivastava, B.N., et al.	1969		4.2			4.76	Same fabrication method as the above specimen.
104	103	Clark, A.F., Childs, G.E., and Wallace, G.H.	1970	V	4.0-273	Cartridge Brass	70.34	29.61	<0.1 each of Fe and Pb; 6.35 mm diameter x 152 mm long; machined; grain size 0.019 mm.
105	103	Clark, A.F., et al.	1970	V	4.0-273	Commercial Bronze	~89	10.01	<0.1 each of Fe and Pb; 6.35 mm diameter x 152 mm long; machined and annealed; grain size 0.051 mm.
106	103	Clark, A.F., et al.	1970	V	4.0-273	Red Brass	~84	15.33	<0.1 each of Fe, Mg, and Ag; 6.35 mm diameter x 152 mm long; cold-drawn; grain size 0.025 mm.
107*	252	Maxwell, E.	1946		293	Yellow Brass	80	20	Nominal composition; drawn; measuring temperature not given, here designated as 20 C.
108*	252	Maxwell, E.	1946		293	Yellow Brass	80	20	Similar to the above specimen but with machined surface.
109	253	Domenicali, C.A. and Otter, F.A.	1954		600			3.26	Calculated composition (3.17 a/o Zn).
110	253	Domenicali, C.A. and Otter, F.A.	1954		600			5.37	Calculated composition (5.23 a/o Zn).
111	253	Domenicali, C.A. and Otter, F.A.	1954		600			8.50	Calculated composition (8.28 a/o Zn).
112	254	Crisp, R.S., Henry, W.G., and Schröder, P.A.	1964	A	4.2, 290			0.45	Calculated composition (0.44 a/o Zn); same original materials and fabrication method as the specimen for Data Set No. 57.
113*	254	Crisp, R.S., et al.	1964	A	4.2, 290			0.93	Calculated composition (0.90 a/o Zn); similar to the above specimen.
114*	254	Crisp, R.S., et al.	1964	A	4.2, 290			1.39	Calculated composition (1.35 a/o Zn); similar to the above specimen.
115*	254	Crisp, R.S., et al.	1964	A	4.2, 290			3.01	Calculated composition (2.93 a/o Zn); similar to the above specimen.
116*	254	Crisp, R.S., et al.	1964	A	4.2, 290			5.98	Calculated composition (5.82 a/o Zn); similar to the above specimen.
117*	254	Crisp, R.S., et al.	1964	A	4.2, 290			10.48	Calculated composition (10.22 a/o Zn); similar to the above specimen but quenched from 575 C after annealing.
118	254	Crisp, R.S., et al.	1964	A	4.2, 290			14.22	Calculated composition (13.88 a/o Zn); similar to the above specimen but without quenching.

* Not shown in figure.

TABLE 37. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Zn	Composition (continued), Specifications, and Remarks
119*	254	Crisp, R.S., Henry, W.G., and Schröder, P.A.	1964	A	4.2, 290			18.89	Calculated composition (18.46 a/o Zn); similar to the above specimen but quenched from 575 C after annealing.
120*	254	Crisp, R.S., et al.	1964	A	4.2, 290			24.35	Calculated composition (23.83 a/o Zn); similar to the above specimen.
121*	255	Muto, Y. and Noto, K.	1964	A	4.2, 293			2.70	Calculated composition (2.63 a/o Zn); 99.9+ pure; prepared from 99.998 pure Cu supplied by Furukawa Denki Kogyo Co.; after melting constituent metals together, ingot quenched and annealed in vacuum at 750 C for 6 hr, drawn into wire and annealed in vacuum at 450 C for 5 hr.
122*	255	Muto, Y. and Noto, K.	1964	A	4.2, 293			2.18	Calculated composition (2.12 a/o Zn); similar to the above specimen.
123*	255	Muto, Y. and Noto, K.	1964	A	4.2, 293			1.90	Calculated composition (1.85 a/o Zn); similar to the above specimen.
124*	255	Muto, Y. and Noto, K.	1964	A	4.2, 293			1.31	Calculated composition (1.27 a/o Zn); similar to the above specimen.
125*	255	Muto, Y. and Noto, K.	1964	A	4.2, 293			0.51	Calculated composition (0.50 a/o Zn); similar to the above specimen.
126*	255	Muto, Y. and Noto, K.	1964	A	4.2, 293			0.29	Calculated composition (0.28 a/o Zn); similar to the above specimen.
127	256	Fusfeld, H.I.	1953		293	Brass		30	Polycrystalline; rod specimen 15 in. long; cold-worked and pulled in tension to 1 percent elongation; measured after annealed at various temperatures, T_a, ranging from 293 to 533 K.
128*	256	Fusfeld, H.I.	1953		293	Brass		30	Similar to the above specimen but pulled to 10% elongation.
129*	256	Fusfeld, H.I.	1953		293	Brass		30	Similar to the above specimen but pulled to 20% elongation.
130	257	Ayers, J.D. and Massalski, T.B.	1972	V	637-778			38.67	Calculated composition (38 a/o Zn); β-phase; 5 x 0.475 x 0.015 cm; cast; heat-treated and quenched.
131	257	Ayers, J.D. and Massalski, T.B.	1972	V	672-766			38.67	The above specimen pulse-heated at 400 C and cooled to room temperature; α-phase.
132	93	Scala, E. and Robertson, W.D.	1953	A	1385-1522			1.29	Calculated composition (1.25 a/o Zn); impurities: < 0.001 each of Fe, Mg, and Si; in liquid state; contained in a refractory insulating tube about 0.6 cm I.D. and 13 cm long.
133*	77	Kapoor, A., Rowlands, J.A., and Woods, S.B.	1974	A	4.2	α-Brass		30.6	Calculated composition (30 a/o Zn); 4 mm diameter x 12 cm long; cast in air, swaged to 0.25 in. thick, and machined to size; cold-worked.
134*	77	Kapoor, A., et al.	1974	A	4.2	α-Brass		30.6	The above specimen annealed in argon at 873 K for 12 hr.
135*	77	Kapoor, A., et al.	1974	A	4.2	α-Brass		30.6	The above specimen reannealed in argon at 973 K for 12 hr.
136*	77	Kapoor, A., et al.	1974	A	4.2	α-Brass		30.6	The above specimen reannealed in argon at 1273 K for 12 hr.
137*	77	Kapoor, A., et al.	1974	A	4.2	Brass		30.6	Single crystal; 3 mm diameter x 15 cm long; supplied by Windsor Metal Crystal Inc., Ltd.
138	130	Sedström, E.	1919		273, 373			7.4	Calculated composition (7.1 a/o Zn); rolled and drawn to 1 mm in diameter; annealed at near melting point for 30 min.
139*	130	Sedström, E.	1919		273, 373			14.4	Calculated composition (14.0 a/o Zn); similar to the above specimen.

* Not shown in figure.

TABLE 37. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Cu	Zn	Composition (continued), Specifications, and Remarks
140	130	Sedström, E.	1919		273, 373			27.9	Calculated composition (27.3 a/o Zn); similar to the above specimen.
141	130	Sedström, E.	1919		273, 373			33.0	Calculated composition (32.4 a/o Zn); similar to the above specimen.
142*	258	Broom, T.	1952	B	90.2-373.2	75/25 brass	74.5		Reported composition: 74.5% Cu, 0.1% Fe, 0.05% Sn, < 0.01% Pb, <<0.01% Mn; annealed at 600 C for 2 h and furnace cooled; successively drawn from 0.072 in diam to 0.022 in diam in liquid oxygen bath at 90.2 K.
143*	258	Broom, T.	1952	B	90.2-373.2	75/25 brass	74.5		Similar to the above specimen; successively drawn from 0.072 in diam to 0.022 in diam in bath of solid carbon dioxide in acetone at 194.7 K.
144*	258	Broom, T.	1952	B	90.2-373.2	95/25 brass	74.5		Similar to the above specimen; successively drawn from 0.072 in diam to 0.022 in diam in bath of ice and water at 273.2 K.
145*	258	Broom, T.	1952	B	90.2-373.2	75/25 brass	74.5		Similar to the above specimen; successively drawn from 0.072 in diam to 0.022 in diam in bath of boiling water at 373.2 K.

* Not shown in figure.

TABLE 38. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

T	ρ
DATA SET 1	
291.2	1.849
DATA SET 2*	
291.2	1.929
DATA SET 3*	
291.2	2.167
DATA SET 4	
6	4.53
78	4.92
201	6.04
279	6.80
DATA SET 5*	
6	4.11
78	4.54
200	5.72
277	6.46
DATA SET 6	
6	3.95
79	4.41
200	5.65
278	6.42
DATA SET 7*	
5	3.87
79	4.37
199	5.62
278	6.40
DATA SET 8	
273.2	4.6
323.2	5.2
373.2	5.8
423.2	6.8
473.2	7.8
523.2	9.0
DATA SET 8 (cont.)	
573.2	10.2
623.2	12.1
673.2	14.4
715.2	17.7
723.2	17.9*
773.2	18.4
823.2	18.9*
873.2	19.4
923.2	20.0
973.2	20.6
DATA SET 9	
4.2	0.56
90	0.87
293	2.27
DATA SET 10	
4.2	1.20
90	1.57
293	3.00
DATA SET 11	
4.2	1.94
90	2.31
293	3.89
DATA SET 12	
14.3	3.77
20.4	3.77
63.5	4.08
77.3	4.23
90.2	4.35
296.1	6.39
DATA SET 13*	
14.3	3.67
20.4	3.67
63.5	4.00
77.3	4.17
90.2	4.30
111.6	4.54
DATA SET 13 (cont.)*	
146.0	4.91
169.5	5.20
292.9	6.46
DATA SET 14	
14.3	3.19
20.4	3.19
63.5	3.43
77.3	3.57
90.2	3.68
111.6	3.85
146.0	4.19
169.5	4.41
292.9	5.51
DATA SET 15*	
14.3	2.83
20.4	2.83
63.5	3.05
77.3	3.15
90.2	3.26
111.6	3.41
146.0	3.72
169.5	3.95
292.9	4.94
DATA SET 16	
14.3	1.89
20.4	1.89
63.5	2.10
77.3	2.21
90.2	2.32
111.6	2.46
146.0	2.75
169.5	2.97
292.9	3.92
DATA SET 17*	
14.3	1.04
20.4	1.04
63.5	1.26
77.3	1.32
DATA SET 17 (cont.)*	
90.2	1.47
111.6	1.64
146.0	1.90
169.5	2.11
292.9	3.01
DATA SET 18	
14.3	0.87
20.4	0.87
63.5	1.06
77.3	1.17
90.2	1.27
111.6	1.39
146.0	1.67
169.5	1.85
292.9	2.70
DATA SET 19	
14.3	0.34
20.4	0.34
63.5	0.50
77.0	0.57
90.2	0.67
296.3	2.10
DATA SET 20*	
14.3	0.17
20.4	0.17
63.5	0.34
77.3	0.39
90.2	0.48
111.6	0.61
146.0	0.86
169.5	1.03
292.9	1.90
DATA SET 21	
14.3	0.10
20.4	0.10
63.5	0.26
77.3	0.33
90.2	0.40
DATA SET 21 (cont.)	
111.6	0.54
146.0	0.78
169.5	0.96
292.9	1.82
DATA SET 22	
14.3	5.15
20.4	5.13
63.5	5.42
77.3	5.54
90.2	5.69
296.7	7.71
DATA SET 23*	
14.3	3.95
20.4	3.95
63.5	4.18
77.3	4.31
90.2	4.43
296.7	6.22
DATA SET 24*	
14.3	3.41
20.4	3.41
63.5	3.60
77.3	3.72
90.2	3.83
110.6	4.00
146.0	4.28
169.5	4.50
293.1	5.50
DATA SET 25	
14.3	2.19
20.4	2.21
63.5	2.38
77.3	2.48
90.2	2.58
296.7	4.17
DATA SET 26*	
14.3	1.13
20.4	1.12
63.5	1.36
77.3	1.48
90.2	1.60
296.7	3.10
DATA SET 27	
14.3	1.05
20.4	1.04
63.5	1.20
77.3	1.29
90.2	1.37
296.7	2.81
DATA SET 28	
14.3	0.37
20.4	0.37
63.5	0.55
77.3	0.65
90.2	0.75
296.7	2.19
DATA SET 29*	
14.3	0.23
20.4	0.23
63.5	0.37
77.3	0.45
90.2	0.55
295.9	1.96
DATA SET 30	
14.3	0.15
20.4	0.15
63.5	0.30
77.3	0.38
90.2	0.47
296.7	1.87
DATA SET 31	
77	0.49

* Not shown in figure.

TABLE 38. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 31 (cont.)	
195	1.33
273	1.82
373	2.50
DATA SET 32*	
77	0.75
195	1.58
273	2.08
373	2.85
DATA SET 33	
77	1.20
195	2.03
273	2.58
373	3.28
DATA SET 34*	
77	1.53
195	2.41
273	2.94
373	3.68
DATA SET 35*	
77	1.70
195	2.61
273	3.13
373	3.89
DATA SET 36	
77	2.00
195	2.83
273	3.43
373	4.19
DATA SET 37*	
77	2.18
195	3.06
273	3.66
373	4.46
DATA SET 38*	
77	2.45
195	3.46
273	3.99
373	4.80
DATA SET 39*	
77	2.66
195	3.69
273	4.26
373	5.08
DATA SET 40	
77	2.90
195	3.81
273	4.52
373	5.40
DATA SET 41*	
77	2.94
195	4.01
273	4.59
373	5.43
DATA SET 42*	
77	3.03
195	4.11
273	4.72
373	5.56
DATA SET 43*	
77	3.25
195	4.35
273	5.01
373	5.56
DATA SET 44	
77	3.33
195	4.42
273	5.14
373	6.03
DATA SET 45*	
77	3.42
195	4.57
273	5.28
373	6.18
DATA SET 46*	
77	3.52
195	4.70
273	5.40
373	6.33
DATA SET 47*	
77	3.52
195	4.75
273	5.44
373	6.38
DATA SET 48*	
77	3.69
195	5.00
273	5.74
373	6.73
DATA SET 49	
77	3.89
195	5.21
273	5.94
373	7.07
DATA SET 50*	
77	3.83
195	5.13
273	5.95
373	6.97
DATA SET 51	
290	1.77
375	2.33
DATA SET 52*	
290	1.96
375	2.53
DATA SET 53*	
290	2.02
375	2.59
DATA SET 54	
290	2.33
375	2.90
DATA SET 55*	
290	2.78
375	3.36
DATA SET 56*	
290	3.24
375	3.84
DATA SET 57	
5	0.224
25	0.224
35	0.241
45	0.266
55	0.310
65	0.363
75	0.425
100	0.600
150	0.933
200	1.265
250	1.597
298	1.925
DATA SET 58*	
7	0.603
20	0.603
30	0.617
45	0.665
55	0.705
75	0.829
DATA SET 58 (cont.)*	
100	1.000
150	1.350
200	1.699
250	2.045
297	2.361
DATA SET 59	
7	0.689
20	0.689
35	0.716
50	0.768
60	0.823
75	0.926
100	1.099
150	1.450
200	1.798
250	2.156
298	2.485
DATA SET 60	
5	1.256
15	1.256
25	1.268
35	1.297
45	1.334
55	1.378
75	1.512
100	1.705
150	2.069
200	2.443
250	2.809
298	3.163
DATA SET 61*	
7	1.934
15	1.934
25	1.947
35	1.982
45	2.027
55	2.070
65	2.138
75	2.221
100	2.419
DATA SET 61 (cont.)*	
150	2.807
200	3.027
250	3.584
297	3.939
DATA SET 62	
5	2.325
15	2.325
25	2.341
35	2.381
45	2.426
55	2.492
75	2.645
100	2.852
150	3.258
200	3.681
237	3.974
DATA SET 63*	
7	2.743
15	2.743
25	2.762
35	2.800
45	2.854
55	2.932
75	3.094
100	3.313
150	3.748
200	4.191
250	4.624
299	5.033
DATA SET 64	
7	3.221
15	3.221
25	3.241
35	3.278
45	3.340
55	3.414
75	3.619
100	3.892
150	4.377
200	4.876

* Not shown in figure.

TABLE 38. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 64 (cont.)	
250	5.356
296	5.775
DATA SET 65*	
4	3.576
15	3.576
25	3.619
35	3.675
46	3.762
75	4.092
100	4.395
150	4.970
200	5.541
237	5.945
DATA SET 66*	
20	0.688
78	0.864
299	3.850
DATA SET 67*	
293.2	1.809
DATA SET 68*	
293.2	1.875
DATA SET 69*	
293.2	2.097
DATA SET 70*	
293.2	2.732
473.2	3.967
DATA SET 71	
293.2	3.025
473.2	4.290
DATA SET 72*	
293.2	3.954
DATA SET 73*	
293.2	4.973
DATA SET 74*	
293.2	5.417
DATA SET 75*	
293.2	5.988
DATA SET 76*	
293.2	4.200
DATA SET 77*	
293.2	6.306
DATA SET 78	
293.2	6.525
DATA SET 79*	
293.2	4.886
DATA SET 80	
293.2	6.398
473.2	8.170
DATA SET 81	
4.2	0.425
DATA SET 82	
4.2	0.38
DATA SET 83*	
4.2	1.22
DATA SET 84*	
4.2	1.12
DATA SET 85*	
4.2	1.88
DATA SET 86	
4.2	2.97
DATA SET 87	
4.2	4.31
DATA SET 88*	
4.2	3.60
DATA SET 89*	
4.2	0.563
90	0.873
293	2.273
DATA SET 90	
4.2	1.20
90	1.53
293	3.00
DATA SET 91*	
4.2	1.94
90	2.31
293	3.89
DATA SET 92	
4.2	4.59
90	5.11
293	7.27
DATA SET 93	
4.2	4.20
90	4.84
293	6.88
DATA SET 94*	
4.2	3.90
90	4.49
293	6.58
DATA SET 95*	
90	3.711
273	5.714
DATA SET 96*	
90	3.655
273	5.634
DATA SET 97	
1.05	1.13
4.2	1.08
DATA SET 98	
1.05	2.55
4.2	2.36
DATA SET 99*	
1.05	2.73
4.2	2.58
DATA SET 100	
1.05	4.22
4.2	4.10
DATA SET 101	
4.2	3.78
298.2	6.65
DATA SET 102*	
4.2	0.549
DATA SET 103*	
4.2	1.043
DATA SET 104	
4.0	4.22
19.65	4.22
75.75	4.65
192.4	5.85
273	6.65
DATA SET 105	
4.0	2.11
19.65	2.10
75.75	2.38
192.4	3.29
273	3.90
DATA SET 106	
4.0	2.74
19.65	2.72
75.75	3.02
192.4	4.00
273	4.66
DATA SET 107*	
293	6.37
DATA SET 108*	
293	6.37
DATA SET 109	
600	4.5
DATA SET 110	
600	5.3
DATA SET 111	
600	6.2
DATA SET 112	
4.2	0.124
290	1.77
DATA SET 113*	
4.2	0.225
290	1.86
DATA SET 114*	
4.2	0.337
290	2.02
DATA SET 115*	
4.2	0.69
290	2.43
DATA SET 116*	
4.2	1.27
290	3.10
DATA SET 117*	
4.2	1.66
290	3.79
DATA SET 118	
4.2	2.34
290	4.38
DATA SET 119*	
4.2	2.80
290	5.00
DATA SET 120*	
4.2	3.02
290	5.40
DATA SET 121*	
4.2	0.509
293.2	2.23
DATA SET 122*	
4.2	0.431
293.2	2.16
DATA SET 123*	
4.2	0.302
293.2	2.05
DATA SET 124*	
4.2	0.220
293.2	1.90

* Not shown in figure.

TABLE 38. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER + ZINC ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 125*	
4.2	0.130
293.2	1.81
DATA SET 126*	
4.2	0.0452
293.2	1.74

T_a(K)	ρ
DATA SET 127 (T = 293.2 K)	
293	5.995
366	5.998
422	5.943
478	5.938
533	5.961
DATA SET 128* (T = 293.2 K)	
293	6.003
366	6.042
422	5.983
478	5.996
533	6.002
DATA SET 129* (T = 293.2 K)	
293	6.013
366	6.070
422	6.059
478	6.033
533	6.083

T	ρ
DATA SET 130	
637	13.0
644	13.3*
646	13.4*
658	13.3*
669	13.8*
670	13.7
672	13.8*
DATA SET 130 (cont.)	
685	13.9*
691	14.0*
691	14.1*
692	14.2*
698	14.1*
701	14.4
704	14.8*
708	14.5*
710	14.3*
722	14.6*
725	14.9
734	14.8*
739	15.3*
755	15.5*
778	15.7*
DATA SET 131	
672	11.9
686	11.9*
696	12.4
703	12.5*
716	12.7*
720	12.8*
720	12.9*
723	12.9*
729	12.8*
732	13.0*
734	13.1*
738	13.1*
740	13.0
752	13.2*
755	13.3
764	13.3*
769	13.6*
786	14.3
DATA SET 132	
1385	23.83
1428	24.63
1468	24.75
1522	26.70
DATA SET 133*	
4.2	4.59
DATA SET 134*	
4.2	3.82
DATA SET 135*	
4.2	3.77
DATA SET 136*	
4.2	3.86
DATA SET 137*	
4.2	3.53
DATA SET 138	
273.2	4.39
373.2	5.65
DATA SET 139*	
273.2	6.13
373.2	7.04
DATA SET 140	
273.2	7.63
373.2	8.00
DATA SET 141	
273.2	7.94
373.2	8.40

ln ($A_{ann.}$/ $A_{def.}$)	ρ
DATA SET 142* (T = 373.2 K)	
0.00	6.70
0.22	6.85
0.46	7.16
0.72	7.34
0.93	7.50
1.20	7.57
1.40	7.66
DATA SET 142 (cont.)* (T = 373.2 K)	
1.67	7.68
1.88	7.73
2.12	7.78
2.33	7.80
DATA SET 143* (T = 273.2 K)	
0.00	5.84
0.23	6.19
0.53	6.58
0.72	6.76
0.93	6.95
1.17	7.08
1.39	7.17
1.64	7.22
1.86	7.28
2.11	7.30
2.33	7.33
DATA SET 144* (T = 194.7 K)	
0.00	5.10
0.22	5.56
0.53	6.06
0.74	6.45
0.95	6.75
1.07	6.94
1.46	7.03
1.66	7.25
1.94	7.36
2.12	7.26
DATA SET 145* (T = 90.2 K)	
0.00	4.09
0.22	4.63
0.51	6.28
0.72	5.62
0.93	5.86
1.18	5.96
1.40	6.25
1.67	6.66
1.95	6.43
2.12	6.66

* Not shown in figure.

TABLE 39. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF ZINC + COPPER ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Zn	Composition (weight percent) Cu	Composition (continued), Specifications, and Remarks
1	228	Yonemitsu, K. and Sato, T.	1958		298-789	CuZn		49.29	Calculated composition; 15.0 x 6.0 x 0.34 mm; 99.98% Cu and 99.98% Zn melted together in a Tammann tube and cast into a small plate 2 mm thick, annealed in the argon vapor for 1 hr at 500 C, polished by sand papers; measurements done while heating at a rate of 75 Ch^{-1} from room temperature to 440 C and at a rate of 25 Ch^{-1} from 440 C to 517 C.
2	228	Yonemitsu, K. and Sato, T.	1958		299	CuZn		49.29	The above specimen measured after quenching from 517 C in air.
3	259	Sato, T. and Noguchi, S.	1957	A	4.2-293	Gamma Brass		41.6	Prepared from 99.95 Zn and 99.98 Cu; melted under a mixture of Sodium Chloride and potassium chloride, sucked up into quartz tubes of 1~2 mm diameter, sealed with argon gas, annealed for 50 hr at 550~600 C, then cooled slowly down to room temperature.
4	259	Sato, T. and Noguchi, S.	1957	A	4.2-293	Gamma Brass		38.0	Similar to the above specimen.
5	259	Sato, T. and Noguchi, S.	1957	A	4.2-293	Gamma Brass		35.4	Similar to the above specimen.
6	259	Sato, T. and Noguchi, S.	1957	A	4.2-293	Gamma Brass		33.3	Similar to the above specimen.
7	259	Sato, T. and Noguchi, S.	1957	A	4.2-293	Gamma Brass		31.5	Similar to the above specimen.
8	260	Martin, M.C.	1963	A	295.2	β-brass		49.43	Calculated composition (Cu: Zn a/o = 1.0055); 99.9 pure; single crystal; supplied by Monocrystals Corp., Cleveland; annealed at 400 C for 1 hr, cooled to room temperature in furnace; quenched; measured after quenching at different temperatures ranging from 20 to 680 C.
9	93	Scala, E. and Robertson, W.D.	1953	A	700-1093			0.968	Calculated composition (0.996 a/o Cu); impurities: <0.001 Pb and Si; in liquid state; contained in a refractory insulating tube about 0.6 cm I.D. and 13 cm long.
10*	93	Scala, E. and Robertson, W.D.	1953	A	986,1037			0.968	The above specimen measured during cooling.
11	109	Materials in Design Engineering	1959		293			0.65-1.25	0.006~0.016 Mg (nominal composition); density 7.17 g cm^{-3}.

* Not shown in figure.

TABLE 40. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF ZINC + COPPER ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

DATA SET 1

T	ρ
298.2	4.95
324.2	5.34
369.2	6.10
422.2	7.11
472.2	7.75
522.2	8.61
566.2	9.51
618.2	12.02
620.2	10.72
712.2	13.01
720.2	13.83
728.2	14.17
733.2	14.45
739.2	14.67*
747.2	15.18
757.2	15.63*
767.2	15.96*
780.2	16.18
705.2	13.67*
737.2	14.68*
746.2	15.14*
759.2	15.74*
771.2	16.01*
789.2	16.46*

DATA SET 2

T	ρ
299.2	5.00

DATA SET 3

T	ρ
4.2	5.10
77.4	6.37
293.2	13.04

DATA SET 4

T	ρ
4.2	4.95
77.4	5.58
293.2	12.09

DATA SET 5

T	ρ
4.2	4.01
77.4	5.34
293.2	10.72

DATA SET 6

T	ρ
4.2	2.69
77.4	3.31
293.2	9.12

DATA SET 7

T	ρ
4.2	3.09
77.4	4.24
293.2	10.33

DATA SET 8
(T = 295.2 C)

T_q(K)	ρ
299	4.033
446	4.046
510	4.046
570	4.048
594	4.048*
664	4.146
696	4.327*
711	4.407
741	4.537
753	4.477
769	4.292
798	4.149
820	4.004
870	4.013
923	4.030
954	4.025

DATA SET 9

T	ρ
700	36.7
754	36.2
814	35.5
870	35.3
904	35.3
932	36.6
982	36.1
1038	37.0
1093	37.2

DATA SET 10*

T	ρ
986	35.6
1037	36.3

DATA SET 11

T	ρ
293.2	6.31

* Not shown in figure.

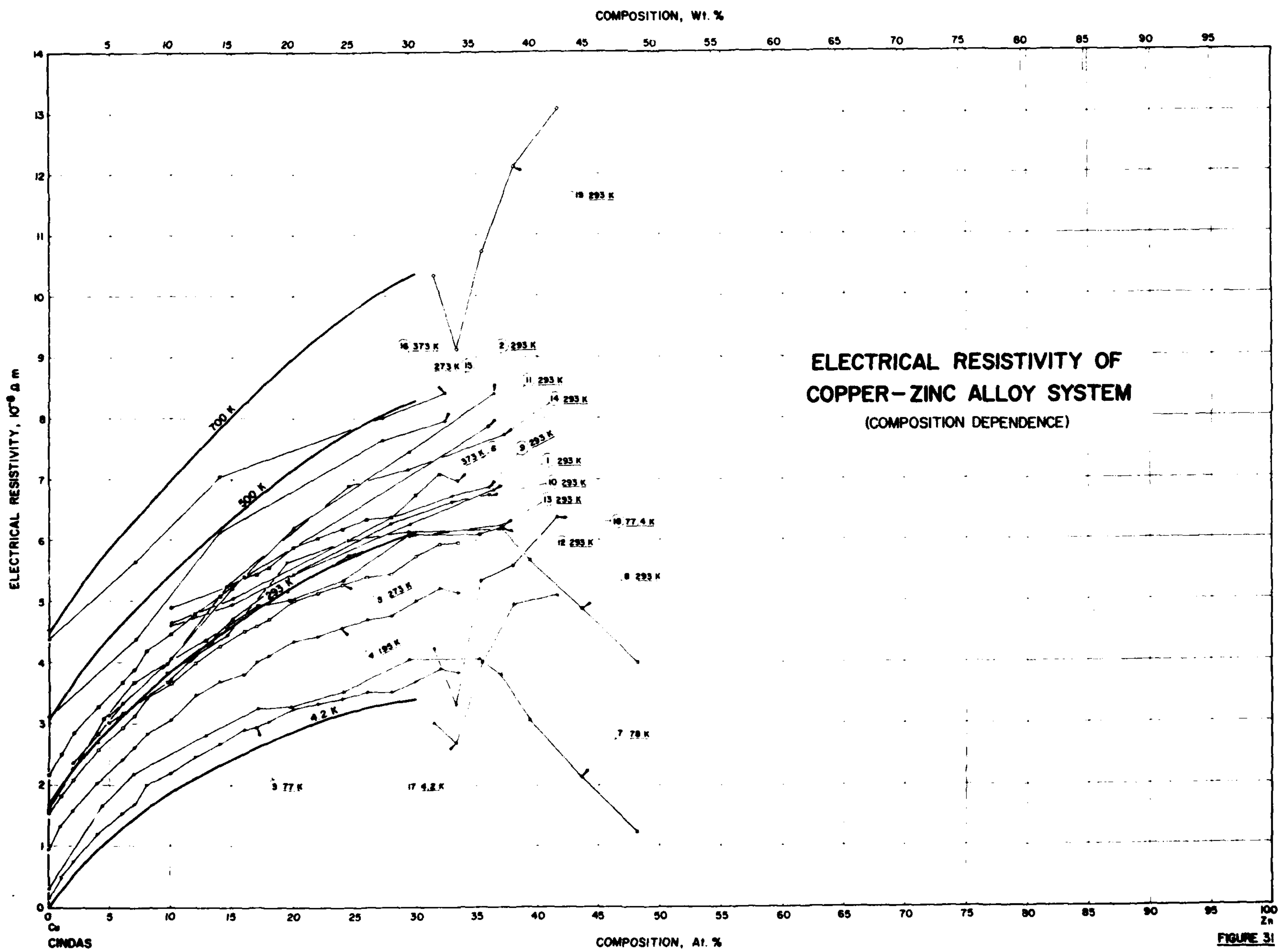

ELECTRICAL RESISTIVITY OF
COPPER-ZINC ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION, Wt. %
COMPOSITION, At. %
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
Cu
Zn
700 K
500 K
293 K
4.2 K
19 293 K
16 373 K
273 K 15
2 293 K
11 293 K
14 293 K
373 K 6
9 293 K
1 293 K
10 293 K
13 293 K
18 77.4 K
12 293 K
8 293 K
5 273 K
4 195 K
7 78 K
3 77 K
17 4.2 K
CINDAS

FIGURE 31

TABLE 41. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF COPPER-ZINC ALLOY SYSTEM (Composition Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Zn)	Composition (weight percent), Specifications, and Remarks
1	98	Köster, W. and Rave, H.P.	1964		293.2	2.0-36	Specimens recrystallized; measuring temperature not given, assigned here as 20 C.
2	98	Köster, W. and Rave, H.P.	1964		293.2	2.0-36	The above specimens 90% cold-worked.
3	239	Argent, B.B. and Lee, K.T.	1964	A	77	0-34	Wire specimens 0.039 in. in diameter; prepared from 99.99+ pure metals by melting in sealed silica capsules, alloys homogenized at >1023 K for one week, rolled and drawn; annealed at 673 K, reannealed at some temperature for 1 h to give a grain size of 0.027 mm, again annealed at 673 K for 1 h, then air cooled rapidly to room temperature; reported error ±2%.
4	239	Argent, B.B. and Lee, K.T.	1964	A	195	0-34	The above specimens.
5	239	Argent, B.B. and Lee, K.T.	1964	A	273	0-34	The above specimens.
6	239	Argent, B.B. and Lee, K.T.	1964	A	373	0-34	The above specimens.
7	261	Aoyama, S. and Ito, T.	1940		78	0-48	Prepared from 99.967+ pure electrolytic copper; annealed in nitrogen at 653 to 673 K for 20 h.
8	261	Aoyama, S. and Ito, T.	1940		293.2	0-48	The above specimens.
9	262	Köster, W. and Schüle, W.	1957		293	10-36	Specimens cold-rolled and recrystallized; measuring temperature not given, assigned here as 20 C.
10	262	Köster, W. and Schüle, W.	1957		293.2	10-36	The above specimens annealed at 773 K and cooled slowly; ordered.
11	262	Köster, W. and Schüle, W.	1957		293.2	10-36	The above specimens 75% cold-worked.
12	263	Presnyakov, A.A., Dautova, L.L., and Klychnikov, Yu. F.	1961	B	293.2	4.9-37	Wire specimens 2 mm in diameter and 500 mm long wound into spirals; heated at 1073 K for 45 min. and quenched in ice water; measuring temperature not given, assigned here as 20 C; reported error ±0.05%.
13	263	Presnyakov, A.A., et al.	1961	B	293.2	4.9-37	The above specimens annealed at 873 K for 1 h.
14	263	Presnyakov, A.A., et al.	1961	B	293.2	4.9-37	The above specimens forged to 80% cold deformation.
15	130	Sedström, E.	1919		273.2	0-32	1 mm wire specimens; rolled and drawn; annealed at near melting point for 30 min.
16	130	Sedström, E.	1919		373.2	0-32	The above specimens.
17	259	Sato, T. and Noguchi, S.	1957	A	4.2	32-42	Specimens prepared from 99.95 Zn and 99.98 Cu; original materials melted in a flux of mixture of NaCl and KCl, sucked up into quartz tubes 1 to 2 mm in diameter and sealed with argon gas, annealed at 550 to 600 C for 50 h, then cooled slowly to room temperature.
18	259	Sato, T. and Noguchi, S.	1957	A	77.4	32-42	The above specimens.
19	259	Sato, T. and Noguchi, S.	1957	A	293.2	32-42	The above specimens.

TABLE 42. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF COPPER-ZINC ALLOY SYSTEM (Composition Dependence)

[Composition, C, a/o Zn; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

C	ρ
DATA SET 1 (T = 293.2 K)	
2.0	2.27
4.0	2.71
6.0	3.17
10.0	3.73
15.0	4.72
20.0	5.44
29.5	6.26
36.4	6.82
DATA SET 2 (T = 293.2 K)	
2.0	2.36
4.0	2.83
6.0	3.34
10.0	4.06
15.0	5.21
20.0	6.21
29.5	7.45
36.4	8.39
DATA SET 3 (T = 77 K)	
0	0.17
1	0.49
2	0.75
4	1.20
6	1.53
7	1.70
8	2.00
10	2.18
12	2.45
14	2.66
16	2.90
17	2.94
18	3.03
20	3.25
22	3.33
24	3.42
26	3.52
28	3.52
30	3.69
32	3.89
33.5	3.83
DATA SET 4 (T = 195 K)	
0	0.96
1	1.33
2	1.58
4	2.03
6	2.41
7	2.61
8	2.83
10	3.06
12	3.46
14	3.69
16	3.81
17	4.01
18	4.11
20	4.35
22	4.42
24	4.57
26	4.70
28	4.75
30	5.00
32	5.21
33.5	5.13
DATA SET 5 (T = 273 K)	
0	1.55
1	1.82
2	2.08
4	2.58
6	2.94
7	3.13
8	3.43
10	3.66
12	3.99
14	4.26
16	4.52
17	4.59
18	4.72
20	5.01
22	5.14
24	5.28
26	5.40
28	5.44
30	5.74
32	5.94
33.5	5.95
DATA SET 6 (T = 373 K)	
0	2.17
1	2.50
2	2.85
4	3.28
6	3.68
7	3.89
8	4.19
10	4.46
12	4.80
14	5.08
16	5.40
17	5.43
18	5.56
20	5.89
22	6.03
24	6.18
26	6.33
28	6.38
30	6.73
32	7.07
33.5	6.97
DATA SET 7 (T = 78 K)	
0	0.232
4.42	1.67
6.99	2.18
12.81	2.81
17.02	3.25
19.81	3.29
24.04	3.53
29.41	4.06
35.30	4.06
37.04	3.80
39.39	3.05
43.68	2.11
48.20	1.21
DATA SET 8 (T = 293.2 K)	
0	1.61
4.42	3.08
6.99	3.69
12.81	4.37
DATA SET 8 (cont.) (T = 293.2 K)	
17.02	4.93
19.81	5.02
24.04	5.35
29.41	6.10
35.30	6.10
37.04	6.21
39.39	5.68
43.68	4.88
48.20	4.00
DATA SET 9 (T = 293.2 K)	
10	4.65
15	5.05
28	6.38
33	6.72
36	6.85
DATA SET 10 (T = 293.2 K)	
10	4.60
15	4.95
28	6.27
33	6.62
36	6.73
DATA SET 11 (T = 293.2 K)	
10	4.90
15	5.27
36	7.85
DATA SET 12 (T = 293.2 K)	
4.9	2.90
9.7	3.83
14.6	4.45
19.5	5.63
24.5	6.01
29.4	6.14
37.3	6.19
DATA SET 13 (T = 293.2 K)	
4.9	3.02
9.7	3.68
14.6	4.56
19.5	5.17
24.5	5.76
29.4	6.09
37.3	6.25
DATA SET 14 (T = 293.2 K)	
4.9	3.14
9.7	3.98
14.6	5.25
24.5	6.89
29.4	7.16
37.3	7.72
DATA SET 15 (T = 273.2 K)	
0	3.12
7.1	4.39
14.0	6.13
27.3	7.63
32.4	7.94
DATA SET 16 (T = 373.2 K)	
0	4.39
7.1	5.65
14.0	7.04
27.3	8.00
32.4	8.40
DATA SET 17 (T = 4.2 K)	
31.5	3.09
33.3	2.69
35.4	4.01
38.0	4.95
41.6	5.10
DATA SET 18 (T = 77.4 K)	
31.5	4.24
33.3	3.31
35.4	5.34
38.0	5.58
41.6	6.37
DATA SET 19 (T = 293.2 K)	
31.5	10.33
33.3	9.12
35.4	10.72
38.0	12.09
41.6	13.04

3.7. Gold-Palladium Alloy System

Twenty data-source references are available for the electrical resistivity of the Au-Pd alloy system. From these references, a total of 93 data sets, six of which are merely single data points, have been extracted along with specimen characterization and measurement information. Forty-three of the data sets are for Au-Pd alloys covering the temperature range from 1.2 to 1400 K, 15 of the data sets are for Pd + Au alloys covering the temperature range from 4 to 1400 K, and 35 of the data sets are isotherms of the electrical resistivity as a function of composition. These experimental data sets are listed in tables 44, 46, and 48 which provide information on specimen characterization and measurement conditions, tabulated in tables 45, 47, and 49, and shown partially in figures 34, 35, and 37. In order to show both functional dependencies of the electrical resistivity, a few of the data sets have been presented in the tables and figures both for temperature dependence and for composition dependence.

Since the electrical resistivity of a specimen depends on the arrangement of its constituent atoms such as ordering, the crystal structure of Au-Pd alloys is briefly discussed here first. The preponderance of data indicates that the Au-Pd alloy system forms a continuous series of solid solutions [264]. However, electron diffraction analyses of thin film specimens by Nagasawa et al. [265] have indicated the existence of long-range ordered structures in Au alloys with 15, 25, and 30 at.% Pd when annealed at temperatures below about 1123 K, the possible existence of such structures near the stoichiometric composition $AuPd_3$, and the absence of such structures in alloys with 10 at.% Pd or 35 to 60 at.% Pd. The authors suggest that the reason why x-ray diffraction studies of bulk specimens have not shown similar evidence of super-lattice structure may be that the time required for homogenization of the alloys is much greater for the bulk specimens than for the thin films.

The existence of short-range order in the Au-Pd alloy system has been established through diffuse x-ray scattering studies of an alloy with 40 at.% Pd by Copeland and Nicholson [266], of alloys with 40, 50, and 60 at.% Pd by Iveronova and Katsnel'son [267,268], and of an alloy with 40 at.% Pd by Lin et al. [269]. These studies further indicated that (1) cold-worked samples can exhibit short-range order, (2) subsequent annealing of cold-worked samples at temperatures from about 373 to 773 K, when followed by quenching, tends to

increase the degree of short-range order, (3) subsequent annealing at temperatures of about 1073 K, when followed by quenching, tends to decrease the degree of short-range order, and (4) subsequent annealing at about 1073 K, when followed by slow cooling, may produce a greater degree of short-range order than any of the other described treatments of cold-worked samples. Devi et al. [270] carried out x-ray investigations of the temperature dependence of the lattice parameter of a 41% Pd alloy, but no deviation from linearity was found up to 873 K, and the authors concluded that measurements of the lattice parameter may not be sensitive to the presence of short-range order in Au-Pd alloys.

The effects of plastic deformation on the electrical resistivity of Au-Pd alloys have been studied by Köster and Halpern [271], Logie et al. [272], and Kim and Flanagan [232]. Normally, the effect of deformation is to increase the electrical resistivity, due to increased scattering from crystal defects introduced by the deformation. However, each of the above studies provided evidence for an anomalous decrease in the resistivity of annealed specimens upon deformation. The anomalous decrease occurs for a wide range of compositions, but it is a maximum for specimens with about 40 at.% Pd. Such specimens, when deformed by about 40% reduction in area, may show a resistivity decrease of nearly 6%. Kim and Flanagan [232], in their consideration of alternative explanations for the anomaly, concluded that cold-work reduces the degree of short-range order present in the specimen. This conclusion, together with the knowledge [232] that short-range ordering causes an increase in the resistivity of Au-Pd alloys, explains the anomaly. Although deformation does produce defects which tend to increase the resistivity, the destruction of short-range order (and the consequent resistivity decrease) overshadows the effect of the defects and results in a net decrease in resistivity.

Studies of the recovery kinetics of cold-worked or quenched specimens upon annealing by Kim and Flanagan [273], Haas and Lücke [274], and Lücke et al. [275] have given further insight into the processes and mechanisms of short-range ordering in Au-Pd alloys. The picture of short-range ordering derived from these studies and ones mentioned earlier is as follows. Above a certain high temperature, short-range ordering does not occur. Below this temperature, the degree of short-range order present at equilibrium increases with decreasing temperature. The formation of short-range order is dependent on the presence of crystal defects (such as vacancies, interstitials, etc.) which allow local

atomic ordering via their migration through the crystal. Such defects may be produced by plastic deformation, quenching, or irradiation. Kim and Flanagan studied the formation of short-range ordering via defects produced by cold-working while Lücke and co-workers primarily studied ordering via defects produced by quenching. As discussed before, the cold-working of annealed specimens may destroy short-range order while at the same time introducing defects which, upon subsequent annealing, may allow the formation of a greater degree of short-range order than was originally present in the annealed specimen. Not only does the formation of short-range order depend on the presence of defects, but the rate of ordering depends on the concentration of defects. The rate of ordering tends to increase with increasing defect concentration and with increasing temperature. In addition, different types of defects may come into play in ordering at different temperatures. Kim and Flanagan, based upon their analysis of ordering rates, described distinct stages of ordering which differ according to the mechanism of ordering and the types of defects involved at different temperatures.

The final state of short-range order achieved at a given temperature may depend on the thermal history of the specimen. For example, Lücke et al. [275] found that equilibrium values of short-range order may be difficult to attain. At low temperatures, the rate of diffusion may be too slow to attain equilibrium. This difficulty may in part be overcome by quenching the specimen from high temperatures, where the vacancy concentration is high, prior to annealing at a lower temperature. The surplus concentration of vacancies 'frozen-in' by the quench then serves to enhance the rate of ordering. In other cases, the excess vacancies may be annealed out before the equilibrium degree of short-range order is attained. With the resultant negligible vacancy concentration, no further ordering can occur and the final degree of short-range order is less than the equilibrium value. A constant resistivity value is thus reached, but it is lower than the resistivity value characteristic of the equilibrium state of short-range order.

The effect of short-range ordering on the magnitude of the electrical resistivity can be sizeable. In their studies of the anomalous decrease in resistivity of annealed alloys upon deformation, Kim and Flanagan [232] found that short-range ordering, even when opposed by the effects of cold-work, may contribute as much as 3% to the electrical resistivity of 25 at.% Pd alloys,

5% to 40 at.% Pd alloys, and 2% to 65 at.% Pd alloys. Similarly, in their studies of the increase of resistivity upon annealing cold-worked specimens, Kim and Flanagan [273] found that short-range ordering may contribute as much as 4 or 5% to the electrical resistivity of 25, 30, and 40 at.% Pd alloys, even when opposed by the effect of the annealing out of crystal defects. Further information was contributed by Lücke et al. [275] who found that the electrical resistivities of specimens in different states of short-range order may differ by as much as 8% for 50 at.% Pd alloys and 1% for 10 at.% Pd alloys.

Lücke et al. [275] (Au + Pd data sets 42 and 43) also investigated the effects of short-range order on the temperature dependence of the electrical resistivity. Using specimens with 50 at.% Pd, they quenched from 1273 K and then annealed at 513 K for different times to establish different degrees of short-range order. The resistivities of the specimens with different degrees of order were then measured from 73 to 473 K. The results showed differences in the magnitude of the resistivity of up to 8% and differences in the magnitude of the resistivity of up to 8% and differences in the temperature derivative of the resistivity (at 273 K) of up to about 3% for the different degrees of short-range order. Rowland et al. [276] (Au + Pd data sets 26-32, Pd + Au data sets 13-15, and Au-Pd data sets 13-28) speculated that a temperature dependence of short-range ordering might be a possible explanation of a very shallow minimum observed around 700 K for alloys with 30 to 60 at.% Pd).

The first step in the generation of recommended electrical resistivity values for this alloy system was the simultaneous examination of the residual resistivity (ρ_0), the resistivity at 300 K (ρ_{300K}), and the difference between the two, in a manner similar to that used in the analysis of the electrical resistivity of the Ag-Pd alloy system. Only three research documents have reported the residual resistivity of Au-Pd alloys over a wide range of compositions. One of the three documents, by Kim [277] (Au-Pd data set 34), was a thesis unavailable in its original form, so the data was extracted as reported by Kim and Flanagan [278] without specimen characterization or measurement information. Of the three, only Hau [279] (Au + Pd data sets 9-14, Pd + Au data sets 1-3, and Au-Pd data sets 4-6) and Rowland et al. [276] reported the resistivities at 4.2 K and near room temperature. The 1% inaccuracy in the measured resistivities, as reported by Hau, was about 4% better than the inaccuracy

reported by Rowland et al., whose measurement of the specimen dimensions was uncertain. Consequently, the values of Hau were followed rather closely in generating recommended values for the residual resistivity.

The residual resistivities of Hau [279] (Au-Pd data set 4) and Rowland et al. [276] (Au-Pd data set 13) show reasonable agreement over much of the composition range, but the values of Rowland et al. are lower than those of Hau by as much as $1.3 \times 10^{-8}\ \Omega\,m$ in the 35 to 55 at.% Pd range. As mentioned above, this is the region where short-range ordering is known to have its maximum effect on the resistivity, with greater degrees of short-range order producing greater residual resistivities. The immediate question of whether the discrepancy between the two sets of data is due to a difference in the degree of short-range order present in the respective specimens is difficult to answer conclusively with the known information. The heat treatment of the specimens of Rowland et al., heating at 1073 K followed by slow cooling, could conceivably produce a significant degree of short-range order, as could the heat treatment of the specimens of Hau which consisted of heating at 973 K followed, presumably, by slow cooling. Unfortunately, Rowland et al. had insuffient knowledge of the structural details of their specimens to be certain of the degree of short-range ordering present and Hau reported that short-range order could not be detected in his experiment. Comparison of the data of Hau with the room-temperature resistivities reported by Köster and Halpern [271] (Au-Pd data sets 1-3) and Lücke et al. [275] (Au + Pd data sets 42-43) for alloys with 40 and 50 at.% Pd show that the resistivities reported by Hau are in all cases lower than the resistivities reported by the other authors. Since the specimens of Köster and Halpern and of Lücke et al. were known to possess some degree of short-range order, this information is consistent with the conclusion that the specimens of Hau possessed less short-range ordering than even the least ordered specimens of these other authors. However, the explanation of the discrepancy between the residual resistivity data of Rowland et al. and of Hau is still unclear.

The discrepancy between the residual resistivity data of Hau and of Rowland et al. raises immediate problems for the generation of recommended values of the electrical resistivity at high temperatures. Rowland et al. are the only investigators to report resistivities at high temperatures for a wide range of compositions. Given the discrepancy in residual resistivities, the

low temperature data of Hau, which were followed closely in generating recommended values, cannot simply or easily be joined with the higher temperature data of Rowland et al. This problem is diminished by an examination of ($\rho_{300K}-\rho_0$), the temperature-dependent part of the resistivity at 300 K. While the residual resistivities of Hau and Rowland et al. differ by as much as $1.3 \times 10^{-8}\ \Omega m$ in the 35 to 55 at.% Pd range, it was found that the temperature-dependent part of their resistivities differed by less than $0.1 \times 10^{-8}\ \Omega m$ at 300 K in this composition range. Apparently, the difference in the specimens of Rowland et al. and Hau is such that only the residual resistivity is affected, and the temperature-dependent part of the resistivity remains largely unaffected. Thus, it becomes possible to synthesize the data of Rowland et al. and Hau if the analysis is carried out primarily in terms of the temperature-dependent part of the resistivity, ($\rho-\rho_0$). This procedure assumes that any differences in the degree of short-range order present in the two sets of specimens have negligible effect on the temperature-dependent parts of the resistivities at all temperatures.

Accordingly, the temperature-dependent part of the resistivity was separated out in all cases where ρ_0 was reported by the authors. In some cases, the authors did not report the residual resistivity, but it still seemed reasonable to estimate ρ_0 for the specimen by using the recommended residual resistivity for the composition in question. In one case, the authors reported the temperature-dependent part of the resistivity directly. Kim and Flanagan [278] reported thermal resistivities based on values of the residual resistivity which were obtained "by extrapolation to the temperature at which the resistivities of pure metals over the same temperature range extrapolate to zero," and not by direct measurement. Comparison of these extrapolations with direct measurements was not possible because neither the extrapolated values nor the total resistivities were reported. Although the gross features of the thermal resistivity as reported by Kim and Flanagan, Hau, and Rowland et al. are similar, the magnitudes of the data of Kim and Flanagan are sometimes inconsistent with the more complete data reported by others. Consequently, the temperature-dependent resistivity data reported by Kim and Flanagan were given little weight in the generation of recommended values.

Smoothed isotherms of the temperature-dependent resistivity as a function of composition were generated by a cross-plotting procedure involving successive

smoothings of the temperature-dependent resistivity as a function of both temperature and composition. The final results for selected temperatures are shown in figure 36. For compositions from 0 to 17 at.% Pd, there is a gradual decrease in the temperature-dependent resistivity from its value for pure gold. This downward slope is supported at low temperatures by the data of Hau and, for dilute alloys up to 700 K by the data of Otter [226] (Au + Pd data sets 1-4). At high temperatures, the data of Rowland et al. also show a negative slope, but one of less magnitude than shown in figure 37. This is because the final smoothed values of the temperature-dependent resistivity pass below the data of Rowland et al. for their 10.5 at.% Pd. These deviations are not inconsistent with an error in sample dimensions, which was suggested as possible by Rowland et al., and result in deviations from the total resistivity reported by Rowland et al. which lie within their experimental inaccuracy of 5%. From a minimum at around 17 at.% Pd, the temperature-dependent resistivity at high temperatures rises to a maximum at about 40 at.% Pd, falls again to a minimum at about 50 at.% Pd, and then rises rapidly to the values for pure palladium.

The final total electrical resistivity values were obtained by adding the residual resistivities to the temperature-dependent resistivities for the selected compositions. The resulting recommended values for Au, Pd, and for 25 Au-Pd binary alloys are presented in table 43 and shown in figures 32 and 33. The recommended values are also shown in figure 37 as a function of composition together with some experimental data. The divergence of the data of Rowland et al. from the recommended values results primarily from differences in the residual resistivity, as discussed above. The recommended values for Au and for Pd are for well-annealed, high-purity specimens, but those values for temperatures below about 100 K are applicable only to Au and Pd having residual electrical resistivities as given at 1 K in table 43. The alloys for which the recommended values are generated have at most a low degree of short-range order and have not been quenched or cold-worked severely. The recommended values cover the temperature range from 1 K to 1400 K and are not corrected for the thermal expansion of the material. The estimated uncertainties in the values for the various alloys and for different temperature ranges are explicitly stated in a footnote to table 43. A few of the values for dilute gold-rich alloys are indicated as provisional because their uncertainties are greater than ±5%.

TABLE 43. RECOMMENDED ELECTRICAL RESISTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM †

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Au: 100.00% (100.00 At.%) Pd: 0.00% (0.00 At.%)		Au: 99.50% (99.08 At.%) Pd: 0.50% (0.92 At.%)		Au: 99.00% (98.16 At.%) Pd: 1.00% (1.84 At.%)		Au: 97.00% (94.58 At.%) Pd: 3.00% (5.42 At.%)		Au: 95.00% (91.12 At.%) Pd: 5.00% (8.88 At.%)		Au: 90.00% (82.94 At.%) Pd: 10.00% (17.06 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	0.0220	1	0.35*	1	0.69*	1	2.02*	1	3.31	1	6.17*
4	0.0220	4	0.35	4	0.69	4	2.02	4	3.31	4	6.17
7	0.0221	7	0.35*	7	0.69*	7	2.02	7	3.31	7	6.17
10	0.0226	10	0.35*	10	0.69*	10	2.02	10	3.31	10	6.17
15	0.0258	15	0.35*‡	15	0.70*‡	15	2.03	15	3.32	15	6.17
20	0.0346‡	20	0.36*‡	20	0.71*‡	20	2.04	20	3.33	20	6.18
25	0.0503‡	25	0.37*‡	25	0.73*‡	25	2.05	25	3.34	25	6.19
30	0.0727‡	30	0.40*‡	30	0.75*‡	30	2.07	30	3.36	30	6.21
40	0.141‡	40	0.46*‡	40	0.80*‡	40	2.13	40	3.41	40	6.26
50	0.222	50	0.54*‡	50	0.88*‡	50	2.21	50	3.49	50	6.33
60	0.309	60	0.63*‡	60	0.97*‡	60	2.29	60	3.57	60	6.41
70	0.396	70	0.72*‡	70	1.05*‡	70	2.37	70	3.65	70	6.49
80	0.482	80	0.80‡	80	1.14‡	80	2.46	80	3.72	80	6.56
90	0.567	90	0.89‡	90	1.23‡	90	2.54	90	3.80	90	6.63
100	0.652	100	0.97‡	100	1.31‡	100	2.61	100	3.88	100	6.70
150	1.063	150	1.38	150	1.71	150	2.99	150	4.25	150	7.07
200	1.464	200	1.78	200	2.10	200	3.38	200	4.63	200	7.45
250	1.865	250	2.20	250	2.51	250	3.80	250	5.04	250	7.84
273	2.052	273	2.38	273	2.69	273	3.99	273	5.21	273	8.01
293	2.214	293	2.54	293	2.86	293	4.14	293	5.35	293	8.17
300	2.271	300	2.59	300	2.91	300	4.20	300	5.41	300	8.22
350	2.683	350	3.00	350	3.32	350	4.58	350	5.79	350	8.56
400	3.102	400	3.41	400	3.73	400	4.97	400	6.17	400	8.93
500	3.962	500	4.24	500	4.55	500	5.75	500	6.93	500	9.69
600	4.853	600	5.11	600	5.41	600	6.55	600	7.71	600	10.47
700	5.780	700	6.02	700	6.31	700	7.40	700	8.53	700	11.30
800	6.755	800	6.99*	800	7.25*	800	8.31*	800	9.43	800	12.19
900	7.787	900	8.01*	900	8.26*	900	9.29*	900	10.40	900	13.11
1000	8.884	1000	9.13*	1000	9.36*	1000	10.36*	1000	11.43	1000	14.08
1100	10.057	1100	10.28*	1100	10.52*	1100	11.51*	1100	12.53	1100	15.14
1200	11.312	1200	11.53*	1200	11.75*	1200	11.75*	1200	13.72	1200	16.31
1300	12.632	1300	12.83*	1300	13.07*	1300	13.97*	1300	14.99*	1300	17.58
1337.58	13.146(s)	1348	13.53*	1355	13.87*	1390	15.20*	1400	16.34*	1400	18.96
1338	31.08(ℓ)										
1700	36.26										

† Uncertainties in the electrical resistivity values are as follows:

100.00 Au - 0.00 Pd: ±1% up to 10 K, ±2.5% above 10 K to 15 K, ±6% above 15 K to 40 K, ±3% above 40 K to 80 K, ±1% above 80 K to 500 K, and ±2.5% above 500 K.
99.50 Au - 0.50 Pd: ±5% up to 10 K, ±9% above 10 K to 100 K, and ±5% above 100 K.
99.00 Au - 1.00 Pd: ±5% up to 10 K, ±7% above 10 K to 100 K, and ±5% above 100 K.
97.00 Au - 3.00 Pd: ±5%.
95.00 Au - 5.00 Pd: ±5%.
90.00 Au - 10.00 Pd: ±4%.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 43. RECOMMENDED ELECTRICAL RESISTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Au: 85.00% (75.38 At.%) Pd: 15.00% (24.62 At.%)		Au: 80.00% (68.36 At.%) Pd: 20.00% (31.64 At.%)		Au: 75.00% (61.84 At.%) Pd: 25.00% (38.16 At.%)		Au: 70.00% (55.76 At.%) Pd: 30.00% (44.24 At.%)		Au: 65.00% (50.08 At.%) Pd: 35.00% (49.92 At.%)		Au: 60.00% (44.76 At.%) Pd: 40.00% (55.24 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	8.57*	1	10.61*	1	12.49	1	15.68*	1	20.57*	1	23.54*
4	8.57*	4	10.61	4	12.49	4	15.68	4	20.57	4	23.54
7	8.57*	7	10.61	7	12.49	7	15.68	7	20.57	7	23.54
10	8.57*	10	10.62	10	12.49	10	15.68	10	20.57	10	23.54
15	8.58*	15	10.63	15	12.51	15	15.69	15	20.58	15	23.56
20	8.59*	20	10.64	20	12.53	20	15.70	20	20.60	20	23.58
25	8.61*	25	10.66	25	12.55	25	15.73	25	20.63	25	23.61
30	8.62*	30	10.68	30	12.57	30	15.76	30	20.67	30	23.65
40	8.67*	40	10.74	40	12.63	40	15.83	40	20.75	40	23.75
50	8.75*	50	10.82	50	12.73	50	15.93	50	20.85	50	23.88
60	8.83*	60	10.91	60	12.82	60	16.03	60	20.97	60	24.03
70	8.91*	70	10.99	70	12.92	70	16.14	70	21.10	70	24.19
80	6.99	80	11.07	80	13.00	80	16.24	80	21.22	80	24.34
90	9.06*	90	11.15	90	13.09	90	16.35	90	21.34	90	24.49
100	9.14*	100	11.23	100	13.19	100	16.44	100	21.45	100	24.64
150	9.52*	150	11.66	150	13.66	150	16.93	150	21.98	150	25.27
200	9.91*	200	12.11	200	14.14	200	17.44	200	22.54	200	25.84
250	10.31*	250	12.55	250	14.65	250	17.97	250	23.07	250	26.42
273	10.50*	273	12.75	273	14.89	273	18.23	273	23.32	273	26.70
293	10.66	293	12.93	293	15.09	293	18.46	293	23.53	293	26.94
300	10.72*	300	12.99	300	15.16	300	18.54	300	23.61	300	27.02
350	11.10*	350	13.45	350	15.73	350	19.10	350	24.14	350	27.63*
400	11.48*	400	13.93	400	16.29	400	19.67	400	24.67	400	28.23*
500	12.28*	500	14.91	500	17.43	500	20.83	500	25.73	500	29.38*
600	13.14*	600	15.91	600	18.61	600	21.92	600	26.74	600	30.41*
700	14.02*	700	16.90	700	19.77	700	22.92	700	27.61	700	31.31*
800	14.93*	800	17.87	800	20.85	800	23.84	800	28.38	800	32.17*
900	15.86*	900	18.87	900	21.88	900	24.75	900	29.17	900	33.05*
1000	16.85*	1000	19.94	1000	22.96	1000	25.69	1000	30.08	1000	34.01*
1100	17.96*	1100	21.12	1100	24.13	1100	26.72	1100	31.13	1100	35.06*
1200	19.19*	1200	22.39	1200	25.38	1200	27.89	1200	32.31	1200	36.20*
1300	20.51*	1300	23.71	1300	26.67	1300	29.16	1300	33.57	1300	37.43*
1400	21.88*	1400	25.02	1400	28.00	1400	30.49	1400	34.84	1400	38.72*

† Uncertainties in the electrical resistivity data are as follows:

85.00 Au - 15.00 Pd: ±3% up to 400 K and ±4% above 400 K.
80.00 Au - 20.00 Pd: ±3%.
75.00 Au - 25.00 Pd: ±4%.
70.00 Au - 30.00 Pd: ±5%.
65.00 Au - 35.00 Pd: ±5%.
60.00 Au - 40.00 Pd: ±3% up to 400 K and ±4% above 400 K.

* In temperature range where no experimental data are available.

TABLE 43. RECOMMENDED ELECTRICAL RESISTIVITY OF GOLD–PALLADIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Au: 55.00% (39.77 At.%) Pd: 45.00% (60.23 At.%)		Au: 50.00% (35.07 At.%) Pd: 50.00% (64.93 At.%)		Au: 45.00% (30.65 At.%) Pd: 55.00% (69.35 At.%)		Au: 40.00% (26.48 At.%) Pd: 60.00% (73.52 At.%)		Au: 35.00% (22.53 At.%) Pd: 65.00% (77.47 At.%)		Au: 30.00% (18.80 At.%) Pd: 70.00% (81.20 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	23.18*	1	21.50*	1	19.57*	1	17.41*	1	15.03*	1	12.59*
4	23.18	4	21.50	4	19.57	4	17.41*	4	15.03*	4	12.59
7	23.18	7	21.50	7	19.57	7	17.41*	7	15.03*	7	12.59
10	23.18	10	21.50	10	19.57	10	17.41*	10	15.03*	10	12.59
15	23.19	15	21.51	15	19.59	15	17.42*	15	15.06*	15	12.61
20	23.21	20	21.53	20	19.63	20	17.45*	20	15.09*	20	12.65
25	23.25	25	21.57	25	19.67	25	17.49*	25	15.13*	25	12.69
30	23.30	30	21.62	30	19.72	30	17.54*	30	15.19*	30	12.75
40	23.41	40	21.75	40	19.84	40	17.70*	40	15.34*	40	12.93
50	23.56	50	21.92	50	20.03	50	17.91*	50	15.57*	50	13.18
60	23.74	60	22.13	60	20.27	60	18.17*	60	15.86*	60	13.48
70	23.94	70	22.37	70	20.54	70	18.47*	70	16.19*	70	13.84
80	24.14	80	22.60	80	20.81	80	18.77	80	16.52*	80	14.21
90	24.34	90	22.85	90	21.09	90	19.09	90	16.87*	90	14.58
100	24.54	100	23.09	100	21.36	100	19.40	100	17.21*	100	14.94
150	25.49	150	24.32	150	22.75	150	20.94	150	18.89*	150	16.74
200	26.41	200	25.55	200	24.14	200	22.47	200	20.51*	200	18.45
250	27.24	250	26.74	250	25.49	250	23.98	250	22.08*	250	20.07
273	27.61	273	27.23	273	26.10	273	24.65	273	22.81*	273	20.82
293	27.93	293	27.63	293	26.61	293	25.23	293	23.44*	293	21.49
300	28.04	300	27.76	300	26.79	300	25.42	300	23.66*	300	21.72
350	28.75	350	28.64*	350	27.91	350	26.74	350	25.15*	350	23.35
400	29.41	400	29.42*	400	28.90	400	27.95	400	26.56*	400	24.92
500	30.62	500	30.81*	500	30.63	500	30.08	500	29.09*	500	27.79
600	31.76	600	32.12*	600	32.16	600	31.94	600	31.30*	600	30.32
700	32.84	700	33.38*	700	33.59	700	33.64	700	33.28*	700	32.58
800	33.88	800	34.59*	800	34.95	800	35.19	800	35.06*	800	34.60
900	34.88	900	35.74*	900	36.25	900	36.62	900	36.67*	900	36.45
1000	35.88	1000	36.83*	1000	37.46	1000	37.94	1000	38.19*	1000	38.22
1100	36.91	1100	37.90*	1100	38.63	1100	39.22	1100	39.67*	1100	39.96
1200	38.00	1200	39.01*	1200	39.81	1200	40.49	1200	41.12*	1200	41.65
1300	39.16	1300	40.16*	1300	41.01	1300	41.75*	1300	42.53*	1300	43.22
1400	40.40	1400	41.31*	1400	42.15	1400	43.00*	1400	43.86*	1400	44.63

† Uncertainties in the electrical resistivity data are as follows:

55.00 Au – 45.00 Pd: ±2% up to 600 K and ±3% above 600 K.
50.00 Au – 50.00 Pd: ±2%
45.00 Au – 55.00 Pd: ±2%
40.00 Au – 60.00 Pd: ±2%
35.00 Au – 65.00 Pd: ±2%
30.00 Au – 70.00 Pd: ±3%

* In temperature range where no experimental data are available.

TABLE 43. RECOMMENDED ELECTRICAL RESISTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Au: 25.00% (15.26 At.%) Pd: 75.00% (84.74 At.%)		Au: 20.00% (11.90 At.%) Pd: 80.00% (88.10 At.%)		Au: 15.00% (8.70 At.%) Pd: 85.00% (91.30 At.%)		Au: 10.00% (5.66 At.%) Pd: 90.00% (94.34 At.%)		Au: 5.00% (2.76 At.%) Pd: 95.00% (97.24 At.%)		Au: 3.00% (1.64 At.%) Pd: 97.00% (98.36 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	10.22*	1	7.97*	1	5.83*	1	3.79*	1	1.85*	1	1.10*
4	10.22	4	7.97*	4	5.83	4	3.79	4	1.85*	4	1.10
7	10.23	7	7.97*	7	5.83	7	3.79	7	1.85*	7	1.10*
10	10.24	10	7.97*	10	5.85	10	3.80	10	1.86*	10	1.10*
15	10.26	15	8.00*	15	5.87	15	3.83	15	1.88*	15	1.12*
20	10.30	20	8.04*	20	5.91	20	3.87	20	1.93*	20	1.15*
25	10.34	25	8.09*	25	5.96	25	3.92	25	1.98*	25	1.20*
30	10.40	30	8.15*	30	6.03	30	4.00	30	2.05*	30	1.26*
40	10.58	40	8.35*	40	6.22	40	4.18	40	2.23*	40	1.46*
50	10.84	50	8.62*	50	6.49	50	4.46	50	2.50*	50	1.73*
60	11.16	60	8.95*	60	6.84	60	4.82	60	2.85*	60	2.08*
70	11.54	70	9.34*	70	7.24	70	5.22	70	3.26*	70	2.48*
80	11.94	80	9.76*	80	7.66	80	5.65	80	3.69*	80	2.92*
90	12.34	90	10.19*	90	8.11	90	6.09	90	4.12*	90	3.34*
100	12.72	100	10.60*	100	8.54	100	6.54	100	4.58*	100	3.80*
150	14.62	150	12.61*	150	10.65	150	8.68	150	6.72*	150	5.94*
200	16.42	200	14.45*	200	12.56	200	10.65	200	8.75*	200	7.98*
250	18.10	250	16.15*	250	14.30	250	12.45	250	10.65*	250	9.89*
273	18.86	273	16.92	273	15.08	273	13.25	273	11.49*	273	10.75
293	19.53	293	17.60	293	15.77	293	13.95	293	12.21	293	11.51
300	19.77	300	17.85	300	16.01	300	14.20*	300	12.46*	300	11.77*
350	21.51	350	19.64*	350	17.80	350	16.00*	350	14.26*	350	13.67*
400	23.19	400	21.41*	400	19.61	400	17.81*	400	16.07*	400	15.49*
500	26.27	500	24.72*	500	23.05	500	21.31*	500	19.58*	500	18.93*
600	29.08	600	27.72*	600	26.18	600	24.52*	600	22.84*	600	22.14*
700	31.60	700	30.42*	700	28.99	700	27.43*	700	25.82*	700	25.12*
800	33.86	800	32.85*	800	31.56	800	30.09*	800	28.54*	800	27.87*
900	35.94	900	35.12*	900	33.95	900	32.56*	900	31.07*	900	30.43*
1000	37.97	1000	37.31*	1000	36.24	1000	34.88*	1000	33.43*	1000	32.83*
1100	39.95	1100	39.40*	1100	38.41	1100	37.05*	1100	35.64*	1100	35.06*
1200	41.78	1200	41.32*	1200	40.39	1200	39.05*	1200	37.68*	1200	37.12*
1300	43.42	1300	43.02*	1300	42.14	1300	40.85*	1300	39.52*	1300	38.98*
1400	44.89	1400	44.51*	1400	43.65	1400	42.44*	1400	41.15*	1400	40.60*

† Uncertainties in the electrical resistivity values are as follows:

25.00 Au - 75.00 Pd: ±3%.
20.00 Au - 80.00 Pd: ±4% up to 100 K and ±2% above 100 K.
15.00 Au - 85.00 Pd: ±4% up to 100 K and ±2% above 100 K.
10.00 Au - 90.00 Pd: ±4% up to 100 K and ±2% above 100 K.
5.00 Au - 95.00 Pd: ±3% up to 10 K, ±4% above 10 K to 100 K, and ±2% above 100 K.
3.00 Au - 97.00 Pd: ±3% up to 10 K, ±5% above 10 K to 100 K, and ±2% above 100 K.

* In temperature range where no experimental data are available.

TABLE 43. RECOMMENDED ELECTRICAL RESISTIVITY OF GOLD-PALLAIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Au: 1.00% (0.54 At.%) Pd: 99.00% (99.46 At.%)		Au: 0.50% (0.27 At.%) Pd: 99.50% (99.73 At.%)		Au: 0.00% (0.00 At.%) Pd: 100.00% (100.00 At.%)	
T	ρ	T	ρ	T	ρ
1	0.36*	1	0.18*	1	0.0200
4	0.36	4	0.18	4	0.0205
7	0.36*	7	0.18*	7	0.0217
10	0.36*	10	0.18*	10	0.0242
15	0.37*	15	0.21*	15	0.0346
20	0.41*	20	0.24*	20	0.0564
25	0.46*	25	0.29*	25	0.0938
30	0.52*	30	0.35*	30	0.151
40	0.70*	40	0.51*	40	0.335
50	0.96*	50	0.78*	50	0.607
60	1.30*	60	1.11*	60	0.940
70	1.70*	70	1.50*	70	1.32
80	2.13*	80	1.93*	80	1.75
90	2.56*	90	2.36*	90	2.19
100	3.01*	100	2.81*	100	2.63
150	5.17*	150	4.98*	150	4.81
200	7.20*	200	7.02*	200	6.89
250	9.17*	250	9.00*	250	8.88
273	10.07	273	9.89	273	9.78
293	10.85*	293	10.67*	293	10.54
300	11.12*	300	10.93*	300	10.80
350	12.99*	350	12.78*	350	12.66
400	14.80*	400	14.59*	400	14.46
500	18.22*	500	18.06*	500	17.89
600	21.43*	600	21.26*	600	21.10
700	24.42*	700	24.25*	700	24.10
800	27.21*	800	27.04*	800	26.89
900	29.79*	900	29.64*	900	29.50
1000	32.19*	1000	32.04*	1000	31.92
1100	34.43*	1100	34.27*	1200	36.21
1200	36.49*	1200	36.34*	1400	39.80
1300	38.37*	1300	38.22*	1600	42.70
1400	40.04*	1400	39.91*	1827	45.14(s)
				1830	83.0(ℓ)
				2000	83.0

† Uncertainties in the electrical resistivity values are as follows:

1.00 Au - 99.00 Pd: ±3% up to 10 K, ±5% above 10 K to 100 K, and ±2% above 100 K.
0.50 Au - 99.50 Pd: ±3% up to 10 K, ±5% above 10 K to 100 K, and ±2% above 100 K.
0.00 Au - 100.00 Pd: ±2% up to 40 K, ±1% above 40 K to 350 K, ±2% above 350 K to 1600 K, ±2.5% above 1600 K to 1827 K, and ±5% above 1827 K.

* In temperature range where no experimental data are available.

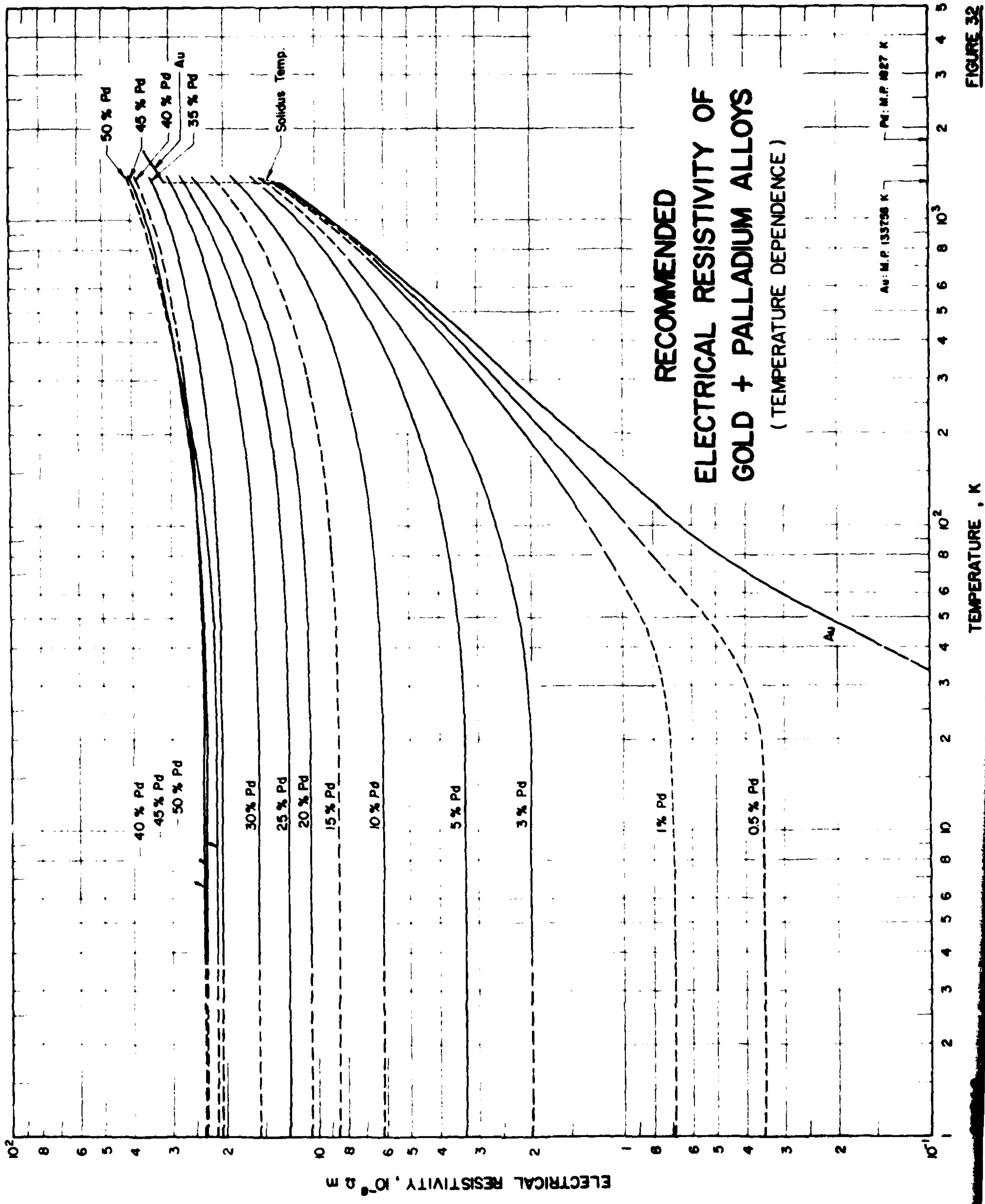

RECOMMENDED
ELECTRICAL RESISTIVITY OF
GOLD + PALLADIUM ALLOYS
(TEMPERATURE DEPENDENCE)
50 % Pd
45 % Pd
40 % Pd
Au
35 % Pd
Solidus Temp.
40 % Pd
45 % Pd
50 % Pd
30 % Pd
25 % Pd
20 % Pd
15 % Pd
10 % Pd
5 % Pd
3 % Pd
1 % Pd
0.5 % Pd
Au
Au: M.P. 1337.58 K
Pd: M.P. 1827 K
TEMPERATURE , K
ELECTRICAL RESISTIVITY , 10^{-8} Ω m

FIGURE 32

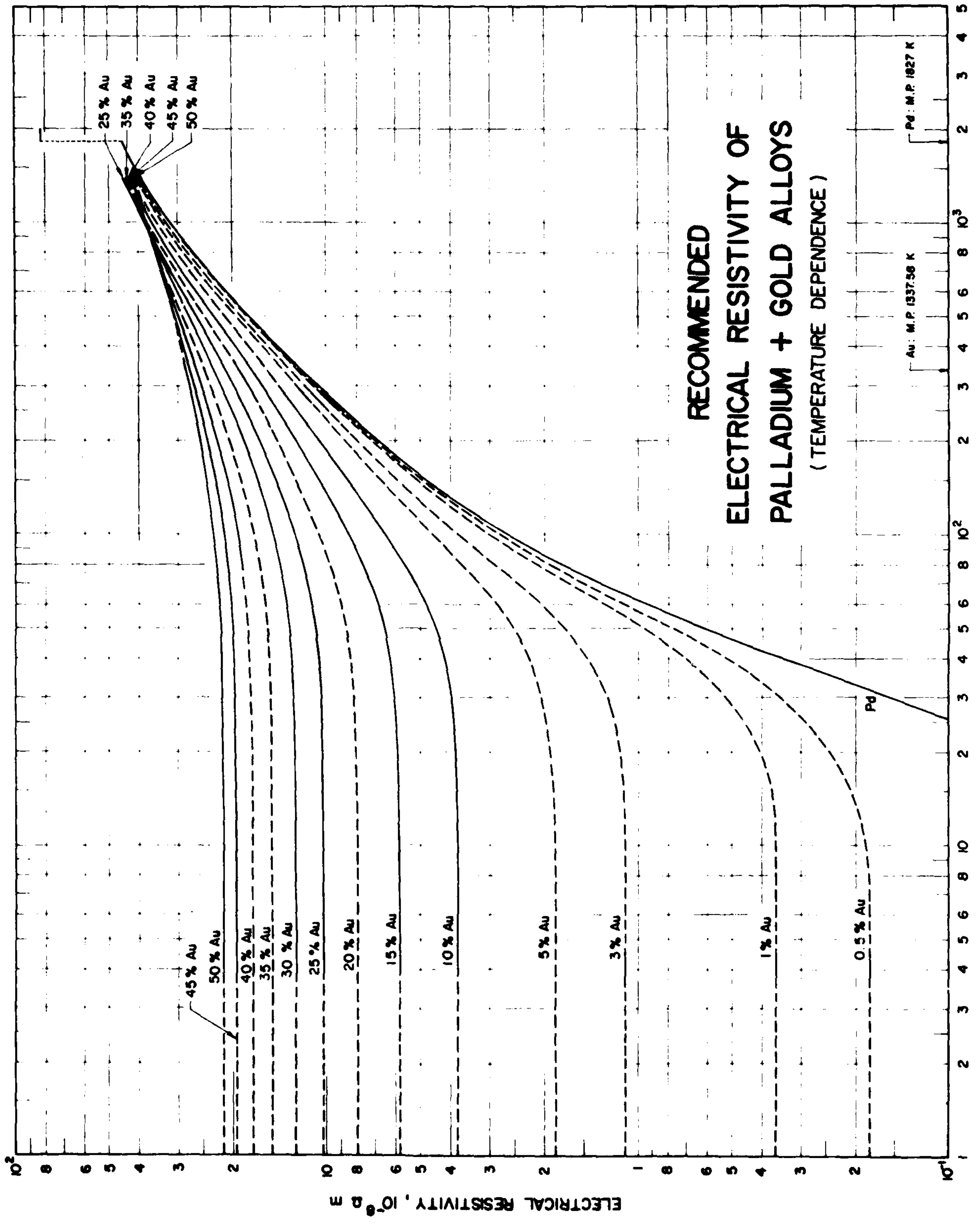

RECOMMENDED
ELECTRICAL RESISTIVITY OF
PALLADIUM + GOLD ALLOYS
(TEMPERATURE DEPENDENCE)
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE , K
Pd : M.P. 1827 K
Au : M.P. 1337.58 K
Pd
25 % Au
35 % Au
40 % Au
45 % Au
50 % Au
45 % Au
50 % Au
40 % Au
35 % Au
30 % Au
25 % Au
20 % Au
15 % Au
10 % Au
5 % Au
3 % Au
1 % Au
0.5 % Au

FIGURE 33

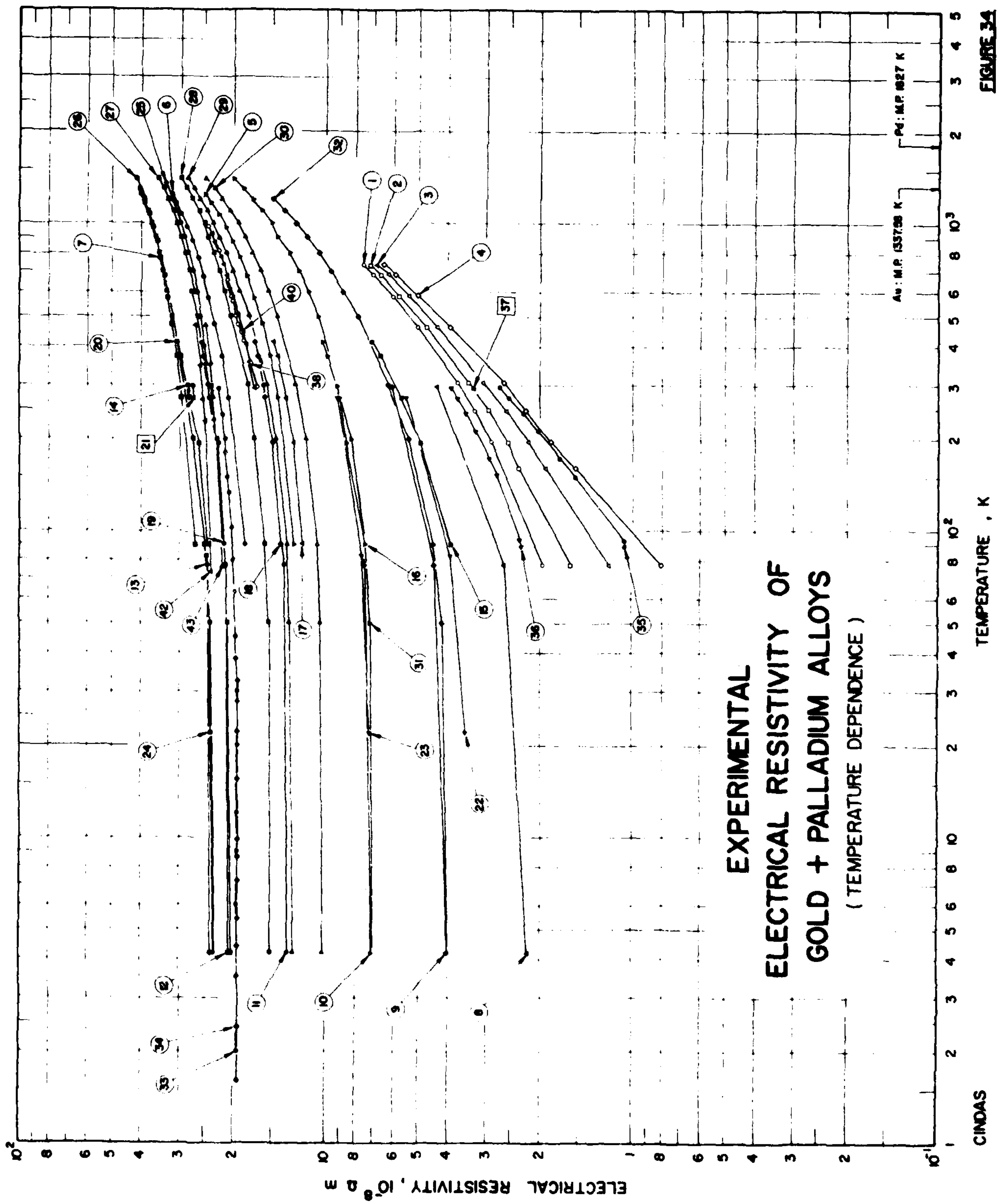
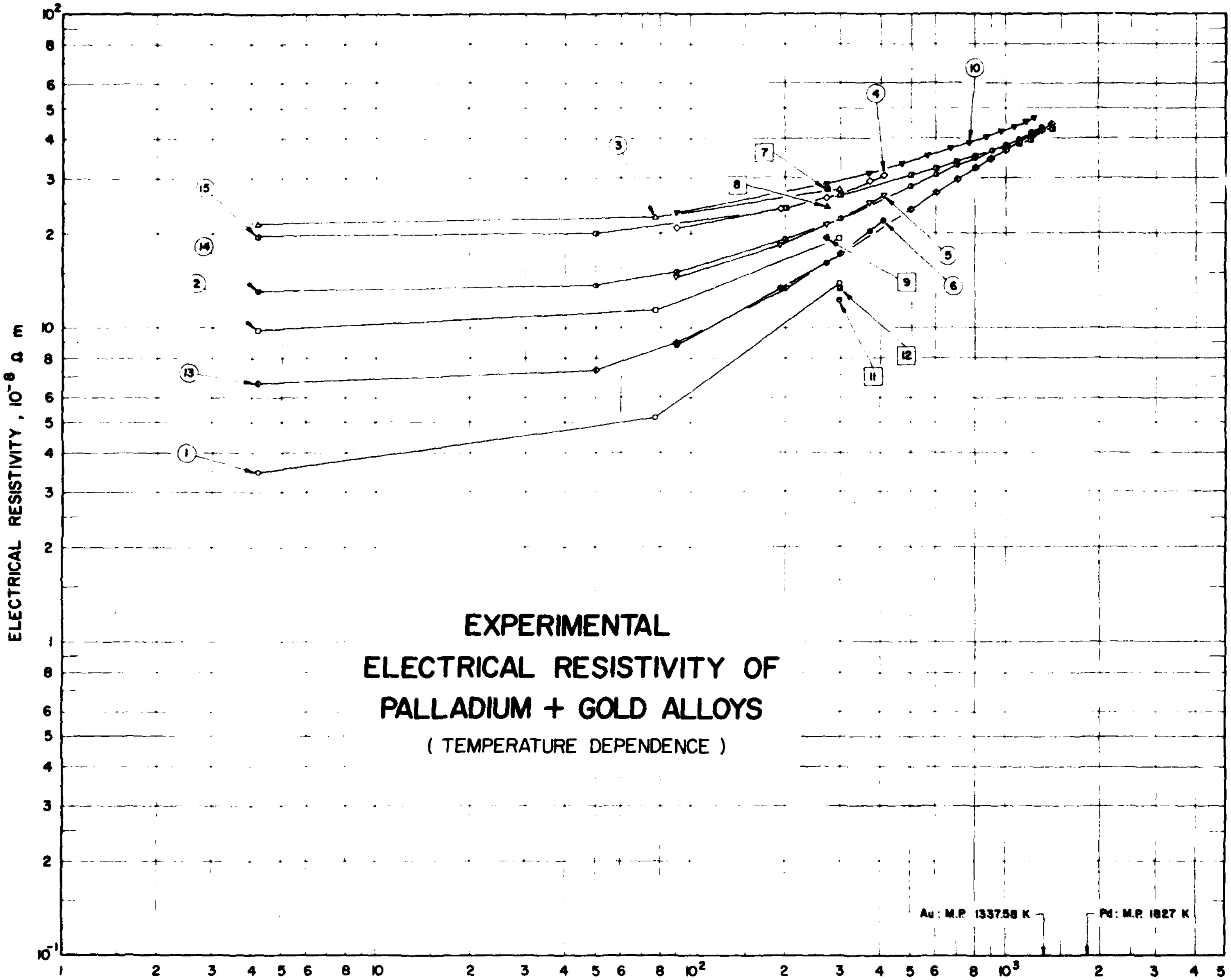

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
GOLD + PALLADIUM ALLOYS
(TEMPERATURE DEPENDENCE)
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE , K
Au: M.P. 1337.58 K
Pd: M.P. 1827 K
CINDAS

FIGURE 34



CINDAS

FIGURE 35

TABLE 44. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + PALLADIUM ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Composition (weight percent) Pd	Composition (continued), Specifications, and Remarks
1	226	Otter, F.A., Jr.	1956	A	77-738			2.20	Calculated composition (3.99 a/o Pd); 99.99+ gold from Handy and Harman and 99.99+ palladium from Bishop Platinum Co. melted in vacuum of less than 10^{-3} mm Hg in alundum crucibles with an induction furnace, super heated approximately 100 K above the melting point, homogenized in vacuum for 24 h at 1173 K, swaged or drawn to wires approximately 30 mils in diam, and annealed for about 1 h at 773 to 823 K; measured in vacuum; data read from figure.
2	226	Otter, F.A., Jr.	1956	A	77-738			1.65	Calculated composition (3.01 a/o Pd); similar to the above specimen.
3	226	Otter, F.A., Jr.	1956	A	77-738			0.99	Calculated composition (1.82 a/o Pd); similar to the above specimen.
4	226	Otter, F.A., Jr.	1956	A	77-738			0.44	Calculated composition (0.81 a/o Pd); similar to the above specimen.
5	280	Conybeare, J.G.G.	1937	V	90-1250		77.5		Calculated composition (65 a/o Au); rod 2 mm in diam and 12 cm long obtained from Johnson Matthey and Co.; annealed until resistance became constant, authors found considerable increase in specific resistance after annealing which was attributed to growth upon annealing of fairly large crystals (observed microscopically) with small fissures between them; measured under vacuum of less than 10^{-6} mm Hg except at highest temperatures where pressure increased to 10^{-4} mm Hg at times due to evolution of gas; resistance ratio RT/R_{273} and resistivity at 273 K, reported; reproducible to 0.1%; extracted from table and converted to resistivity without correcting for thermal expansion.
6	280	Conybeare, J.G.G.	1937	V	90-1250		69.3		Calculated composition (55 a/o Au); similar to the above specimen.
7	280	Conybeare, J.G.G.	1937	V	90-1250		55.2		Calculated composition (40 a/o Au); similar to the above specimen.
8	279	Hau, N.H.	1966	A	4.2-298	A95	96.767		Calculated composition (94.175 a/o Au), determined by weight and lattice parameter (4.0654 Å); 0.7 mm in diam and about 16 cm long; 99.999+ pure Au splatters (0.0002 Ag; <0.0001 Mg, Si, Fe, and Cu) from American Smelting and Refining Co. and 99.99+ pure Pd sponge (with no Fe impurity) from Engelhard Industries Inc. melted together in high-purity recrystallized alumina crucible by induction heating in Ar, molded into slugs, etched, homogenized in Ar for 6.8d at 1123 K, slowly cooled, swaged to smaller diam and drawn to final diam with intermediate anneals at 723 K in Ar, and finally annealed in vacuum of 10^{-6} mm Hg at 973 K for 24 h; uncertainty in temperature 0.01 K above 16 K and 0.1 K below 16 K, temperature controlled to within 0.01 K, uncertainty in resistivity of about 1%; data extracted from table.
9	279	Hau, N.H.	1966	A	4.2-298	A90	93.878		Calculated composition (89.229 a/o Au); similar to the above specimen but with lattice parameter of 4.0549 Å.
10	279	Hau, N.H.	1966	A	4.2-298	A80	88.296		Calculated composition (80.297 a/o Au); similar to the above specimen but with lattice parameter of 4.0364 Å.
11	279	Hau, N.H.	1966	A	4.2-298	A60	73.538		Calculated composition (60.019 a/o Au); similar to the above specimen but with lattice parameter of 3.9988 Å.
12	279	Hau, N.H.	1966	A	4.2-298	A50	65.066		Calculated composition (50.153 a/o Au); similar to the above specimen but with lattice parameter of 3.9821 Å and with intermediate anneals at 973 K as well as 723 K.

TABLE 44. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + PALLADIUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Pd	Composition (continued), Specifications, and Remarks
13	279	Hau, N.H.	1966	A	4.2-298	A45	59.835		Calculated composition (44.590 a/o Au); similar to the above specimen but with lattice parameter of 3.9719 Å.
14	279	Hau, N.H.	1966	A	4.2-298	A40	55.148		Calculated composition (39.858 a/o Au); similar to the above specimen but with lattice parameter of 3.9630 Å and with homogenization for 7.7d rather than 6.8d.
15	131	Röhl, H.	1933		90-413	AP1a		4.99	Calculated composition (8.86 a/o Pd); homogenized for 2 h at 1073 K, heat-treated for 2 h at 1073 K and for 10 h at 573 K; data extracted from table.
16	131	Röhl, H.	1933		90-413	AP1		9.96	Calculated composition (17.0 a/o Pd); similar to the above specimen.
17	131	Röhl, H.	1933		90-413	AP2		20.0	Calculated composition (31.6 a/o Pd); similar to the above specimen.
18	131	Röhl, H.	1933		90-413	AP3a		27.5	Calculated composition (41.2 a/o Pd); similar to the above specimen.
19	131	Röhl, H.	1933		90-413	AP3		35.0	Calculated composition (49.9 a/o Pd); similar to the above specimen.
20	131	Röhl, H.	1933		90-413	AP4		45.0	Calculated composition (60.2 a/o Pd); similar to the above specimen.
21	131	Röhl, H.	1933		273.2	AP8		39.8	Calculated composition (55.0 a/o Pd); similar to the above specimen.
22	128	Grüneisen, E. and Reddemann, H.	1934		22-273	22		4.99	Calculated composition (8.86 a/o Pd); annealed at 1073 K for 2 h; this is Röhl's specimen of Au + Pd data set 15; data extracted from table.
23	128	Grüneisen, E. and Reddemann, H.	1934		22-273	23		9.96	Calculated composition (17.0 a/o Pd); annealed at 1073 K for 2 h; this is Röhl's specimen of Au + Pd data set 16; data extracted from table.
24	128	Grüneisen, E. and Reddemann, H.	1934		22-273	24		39.8	Calculated composition (55.0 a/o Pd); annealed at 1073 K for 2 h; this is Röhl's specimen of Au + Pd data set 21; data extracted from table.
25	281	Laubitz, M.J. and Van der Meer, M.P.	1968	A	300-1350	7674	65.05	34.95	Rod specimen of Platinel 1503, 0.178 cm in diam and 20 cm long supplied by Englehard Industries, Inc; thermoelectric power measured as homogeneity check; annealed at 1100 K for 15 h after specimen had been assembled in measuring apparatus; measured in several cycles of increasing and decreasing temperature; 19 data points were fitted by $\rho = 2.236 \times 10^{-7} + 5.48 \times 10^{-11} T + 2.02 \times 10^{-14} T^2$ Ωm with a root mean square deviation of 0.55% for temperatures between 300 K and 1350 K; residual resistivity ratio, $\rho_{273}/\rho_4 = 1.133$; data uncorrected for thermal expansion; maximum possible error due to all causes known to author ± 0.5%; data calculated from above equation.
26	276	Rowland, T., Cusack, N.E., and Ross, R.G.	1974	A	4-1400		54.2		Calculated composition (39.0 a/o Au), concentration of main components measured to ± 0.3 a/o by chemical and x-ray analysis, spectrographic analysis revealed major trace impurities of 30 ppm Fe, 20 ppm Ag, and 20 ppm Si; wire specimen between 0.31 and 0.38 mm in diam prepared by author at Johnson Matthey and Co. Ltd. from sponges of spectroscopically pure Pd and 99.999 pure Au by pressing sponge into bars, sintering in vacuum at 1173 K for several hours, induction melting in stream of pure argon, cold rolling ingots to 3 mm square rods, and by finally drawing down to final diam; annealed at 1073 K in vacuum for a few hours and slowly furnace cooled; residual resistivity ratio, $\rho_{4.2}/\rho_{273} = 0.8209$; ± 5% uncertainty in resistivity due mainly to uncertain diam; data from tables supplied by author in private communication.

TABLE 44. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + PALLADIUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Pd	Composition (continued), Specifications, and Remarks
27	276	Rowland, T., Cusack, N.E., and Ross, R.G.	1974	A	4-1400		63.5		Calculated composition (48.5 a/o Au); similar to the above specimen, but with major trace impurities of 30 ppm Fe and 30 ppm Ag and $\rho_{4.2}/\rho_{273}$ = 0.8780.
28	276	Rowland, T., et al.	1974	A	4-1400		69.2		Calculated composition (54.8 a/o Au); similar to the above specimen, but with major trace impurities of 50 ppm Fe and 30 ppm Ag and $\rho_{4.2}/\rho_{273}$ = 0.8476.
29	276	Rowland, T., et al.	1974	A	4-1400		73.0		Calculated composition (59.3 a/o Au); similar to the above specimen, but with major trace impurities of 30 ppm Cu, 20 ppm Fe, and 20 ppm Pt and with $\rho_{4.2}/\rho_{273}$ = 0.8318.
30	276	Rowland, T., et al.	1974	A	4-1400		80.5		Calculated composition (69.0 a/o Au); similar to the above specimen, but with major trace impurities of 50 ppm Pt, 20 ppm Ag, and 20 ppm Fe and with $\rho_{4.2}/\rho_{273}$ = 0.8273.
31	276	Rowland, T., et al.	1974	A	4-1400		87.8		Calculated composition (79.5 a/o Au); similar to the above specimen, but with major trace impurities of 50 ppm Fe and 30 ppm Ag and $\rho_{4.2}/\rho_{273}$ = 0.7921.
32	276	Rowland, T., et al.	1974	A	4-1200		94.0		Calculated composition (89.5 a/o Au); similar to the above specimen, but with major trace impurities of 50 ppm Fe and 50 ppm Rh and $\rho_{4.2}/\rho_{273}$ = 0.6611.
33	282	Ugodnikova, D.A., Beilin, B.M., and Tsiovkin, Yu. Yu. N.	1974		2-292		73.5	26.5	Calculated composition (40 a/o Pd); metallographic and x-ray analyses showed single phase structure; 0.1 mm diam wire specimens; annealed from 1073 K; data read from figure.
34	282	Ugodnikova, D.A., et al.	1974		1.6-38.2		73.5	26.5	The above specimen; data read from crude, expanded figure.
35	37	Linde, J.O.	1931		89-296			0.625	Calculated composition (1.15 a/o Pd); mint grade Au and extra pure Pd from Heraeus melted together under vacuum of about 0.1 mm Hg in quartz and magnesium oxide powder crucibles, homogenized 10-20 h at temperature near the melting point, formed into square rod of 1.2 mm thickness, drawn through steel or sapphire dies to wire of 0.75 mm diam and 1.2 cm length, and finally annealed at 773 K; diam measured with micrometer to ± 0.03 mm; data extracted from table.
36	37	Linde, J.O.	1931		89-296			2.46	Calculated composition (4.46 a/o Pd); similar to the above specimen.
37	37	Linde, J.O.	1931		291			1.58	Calculated composition (2.88 a/o Pd); similar to the above specimen.
38	271	Köster, W. and Halpern, T.	1961		295-982			26.5	Calculated composition (40 a/o Pd); 99.95 pure Pd and 99.99 pure Au from Fa. Degussa Hanau melted together, homogenized in vacuum at 1073 to 1223 K for 70 h and furnace-cooled; reduced 98.5% by cold-rolling from a thickness of 7 mm to 0.1 mm without intermediate annealing; data read from figure.
39*	271	Köster, W. and Halpern, T.	1961		294-1072			26.5	The above specimen heated at 1373 K and quenched in water.
40	271	Köster, W. and Halpern, T.	1961		293-923			26.5	The above specimen annealed at 1073 K and cooled slowly in furnace.

* Not shown in figure.

TABLE 44. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + PALLADIUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Composition (weight percent) Pd	Composition (continued), Specifications, and Remarks
41*	283	Bäcklund, N.	1958	A	1.2-4.2			0.157	Calculated composition (0.29 a/o Pd); spectroscopically pure Pd and Au from Johnson, Matthey and Co. Ltd melted together in evacuated silica tubes in high-frequency furnace or wire-wound furnace; ingots rolled slightly, homogenized at 1073-1173 K for about 2 h, and drawn to 0.2 mm diam wire; the sample was one of several which were annealed at about 773 K when quenching from higher temperatures was not necessary; data read from figure.
42	275	Lücke, K., Haas, H., and Schulze, H. A.	1976		73-469			35.1	Calculated composition (50 a/o Pd); 0.1 mm thick foils prepared from 99.998 pure Au and 99.99 pure Pd; quenched from 1273 K and annealed at 513 K prior to measurement; accuracy of resistivity measurements 3×10^{-5}; data read from figure.
43	275	Lücke, K., et al.	1976		76-472			35.1	The above specimen annealed at 513 K for a different period of time in order to produce a different state of short-range order; several different annealing times were used by the authors, but not specified quantitatively; data sets 42 and 43 represent the highest and lowest resistivities produced by varying the annealing time.

* Not shown in figure.

TABLE 45. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD + PALLADIUM ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega m$]

DATA SET 1

T	ρ
77.2	1.96
196.2	2.89
248.2	3.26
306.2	3.71
461.2	5.01
581.2	6.02
682.2	7.04
738.2	7.53

DATA SET 2

T	ρ
77.2	1.58
160.2	2.35
196.2	2.50
248.2	2.94
306.2	3.41
461.2	4.70
581.2	5.77
682.2	6.64
738.2	7.19

DATA SET 3

T	ρ
77.2	1.18
160.2	1.92
196.2	2.19
248.2	2.57
306.2	3.07
461.2	4.32
581.2	5.33
682.2	6.27
738.2	6.85

DATA SET 4

T	ρ
77.2	0.80
160.2	1.53
196.2	1.85
248.2	2.23
306.2	2.62
461.2	3.93
581.2	4.99
682.2	5.93
738.2	6.47

DATA SET 5

T	ρ
90.2	12.7
273.2	14.3
373	15.2
473	16.1
573	17.2
673	18.2
773	19.1
873	20.1
973	21.2
1073	22.4
1173	23.7
1250	24.9

DATA SET 6

T	ρ
90.2	18.4
273.2	20.7
373	21.8
473	23.1
573	24.2
673	25.2
773	26.2
873	27.2
973	28.3
1073	29.6
1173	30.9
1250	32.0

DATA SET 7

T	ρ
90.2	26.6
273.2	29.5
373	30.7
473	31.8
573	32.8
673	33.7
773	34.6
873	35.5
973	36.5
1073	37.8
1173	39.0
1250	40.2

DATA SET 8

T	ρ
4.2	2.182
77.3	2.626
298	4.350

DATA SET 9

T	ρ
4.2	3.993
77.3	4.411
298	6.069

DATA SET 10

T	ρ
4.2	7.041
77.3	7.439
298	9.124

DATA SET 11

T	ρ
4.2	13.20
77.3	13.65
298	15.94

DATA SET 12

T	ρ
4.2	20.51
77.3	21.09
298	23.56

DATA SET 13

T	ρ
4.2	23.57
77.3	24.29
298	27.09

DATA SET 14

T	ρ
4.2	23.19
77.3	24.16*
298	28.06

DATA SET 15

T	ρ
90.2	3.90
194.7	4.91
273.2	5.65
373.2	6.64
413.2	7.02

DATA SET 16

T	ρ
90.2	7.41
194.7	8.57
273.2	8.97
373.2	9.83
413.2	10.2

DATA SET 17

T	ρ
90.2	11.9
194.7	12.8
273.2	13.5
373.2	14.4
413.2	14.8

DATA SET 18

T	ρ
90.2	14.0
194.7	14.9
273.2	15.7
373.2	16.7
413.2	17.0

DATA SET 19

T	ρ
90.2	21.5
194.7	22.4
273.2	23.8
373.2	25.1
413.2	25.5

DATA SET 20

T	ρ
90.2	24.3
194.7	26.0
273.2	27.9
373.2	29.9
413.2	30.6

DATA SET 21

T	ρ
273.2	27.1

DATA SET 22

T	ρ
22	3.48
83	3.94
273	5.44

DATA SET 23

T	ρ
22	7.18
83	7.61
273	9.10

DATA SET 24

T	ρ
22	23.7
83	24.5
273	27.1*

DATA SET 25

T	ρ
300	24.19
350	24.53
400	24.88
450	25.24*
500	25.61
550	25.99*
600	26.38
650	26.78*
700	27.19
750	27.61*
800	28.04
850	28.48*
900	28.93
950	29.39*
1000	29.86
1050	30.34*
1100	30.83
1150	31.33*
1200	31.84
1250	32.37*
1300	32.90*
1350	33.44

DATA SET 26

T	ρ
4.2	23.38*
50	23.80
90	24.75
200	27.15
300	28.90*
500	31.80
600	33.00
700	34.05
800	35.00
900	35.80

DATA SET 26 (cont.)

T	ρ
1000	36.90
1100	38.00
1200	39.10
1300	40.30
1400	41.60

DATA SET 27

T	ρ
4.2	20.72*
50	21.00
90	21.49*
200	22.72
300	23.78*
500	26.02
600	27.30
600	26.90
700	27.85
800	28.60
900	29.40
1000	30.30
1100	31.40
1200	32.65
1300	33.90
1400	35.10

DATA SET 28

T	ρ
4.2	15.07
50	15.32
90	15.75
200	17.05
300	17.95
500	20.22
600	21.35
700	22.26
800	23.05
900	24.00
1000	24.86
1100	25.90
1200	27.04
1300	28.50
1400	29.70

DATA SET 29

T	ρ
4.2	12.76
50	13.10

* Not shown in figure.

TABLE 45. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD + PALLADIUM ALLOYS (Temperature Dependence) (continued)

DATA SET 29 (cont.)

T	ρ
90	13.40
200	14.60
300	15.60
500	17.88
600	19.10
700	20.21
800	21.20
900	22.40
1000	23.30
1100	24.50
1200	25.80
1300	27.00
1400	28.40

DATA SET 30

T	ρ
4.2	10.20
50	10.40
90	10.72
200	11.75
300	12.60
500	14.42
600	15.40
700	16.47
800	17.40
900	18.30
1000	19.40
1100	20.60
1200	21.88
1300	23.20
1400	24.70

DATA SET 31

T	ρ
4.2	7.01*
50	7.18
90	7.49*
200	8.30
300	9.05*
500	10.57
600	11.40
700	12.28
800	13.15
900	14.40
1000	15.00
1100	16.10
1200	17.23
1300	18.70
1400	20.00

DATA SET 32

T	ρ
4.2	3.96*
50	4.18
90	4.47
200	5.37
300	6.22
500	7.85
600	8.70
700	9.60
800	10.50
900	11.50
1000	12.50
1100	13.60
1200	14.80

DATA SET 33

T	ρ
2	19.43
6	19.43
9	19.42
12	19.42
14	19.41*
17	19.41*
20	19.42
24	19.43*
27	19.44*
30	19.45
32	19.47*
34	19.49*
37	19.50*
39	19.51*
42	19.54*
45	19.56
47	19.58*
49	19.60*
53	19.65*
58	19.71*
63	19.78
66	19.82*
69	19.85*
72	19.89*
74	19.92*
78	19.96*
80	20.00
82	20.02*
86	20.08*
91	20.13*
95	20.19*
97	20.22*

DATA SET 33 (cont.)

T	ρ
102	20.28
103	20.32*
108	20.35*
112	20.40*
118	20.46*
123	20.53*
129	20.59*
134	20.65
139	20.69*
142	20.73*
145	20.78*
149	20.81*
150	20.81
152	20.84*
157	20.90*
163	20.97*
168	21.02*
173	21.06*
180	21.14
184	21.19*
188	21.23*
192	21.28*
200	21.35
205	21.40*
207	21.43*
214	21.49*
219	21.54*
227	21.61*
234	21.68*
240	21.74
249	21.83*
257	21.91*
265	21.99*
275	22.08*
292	22.25

DATA SET 34

T	ρ
1.6	19.439
2.4	19.436
3.5	19.433
4.4	19.431
5.4	19.429
6.0	19.426*
7.2	19.424
8.6	19.422
9.8	19.421
11.3	19.420*

DATA SET 34 (cont.)

T	ρ
13.2	19.419*
14.3	19.418*
15.5	19.417
16.9	19.417*
18.7	19.417*
20.7	19.418*
22.0	19.420
23.2	19.423*
24.5	19.426*
25.4	19.429*
26.4	19.434*
27.6	19.440
28.8	19.446*
29.4	19.451*
30.6	19.457*
32.2	19.468
33.8	19.479*
34.8	19.485
36.6	19.498*
38.2	19.511

DATA SET 35

T	ρ
89.0	1.062
93.2	1.063
151.0	1.542
173.2	1.722
211.7	2.029
242.7	2.273
273.2	2.521
291.2	2.666*
295.8	2.705

DATA SET 36

T	ρ
89.0	2.305
93.2	2.337
151.5	2.781
173.2	2.948
212.6	3.254
243.3	3.500
273.2	3.730
291.2	3.873*
295.8	3.908

DATA SET 37

T	ρ
291.2	3.303

DATA SET 38

T	ρ
295	16.9
354	17.6
418	18.6
447	19.0
469	19.5*
500	19.9
566	20.2*
579	20.4
656	21.1
814	22.5
982	24.3

DATA SET 39*

T	ρ
294	16.5
336	17.0
361	17.2
411	17.8
451	18.5
488	19.8
565	20.7
591	20.8
707	21.5
773	22.1
904	23.4
1072	25.4

DATA SET 40

T	ρ
293	17.1
352	17.7
404	18.3
446	18.8
503	19.4
570	20.2
608	20.6
673	21.3
730	21.7
776	22.1
868	23.1
923	23.7

DATA SET 41*

T	ρ
1.2	0.2376
2.0	0.2360
2.7	0.2348
3.5	0.2342
4.2	0.2334

DATA SET 42

T	ρ
73	23.58
228	24.80
269	25.13
348	25.77
469	26.72

DATA SET 43

T	ρ
76	21.83
230	23.04
271	23.34
350	23.96
472	24.87

* Not shown in figure.

TABLE 46. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + GOLD ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Pd	Au	Composition (continued), Specifications, and Remarks
1	279	Hau, N.H.	1966	A	4.2-298	A5		9.228	Calculated composition (5.206 a/o Au), determined by weight and lattice parameter (3.8994 Å); 0.07 mm in diam and about 16 cm long; 99.999+ pure Au splatters (0.0002 Ag, < 0.0001 Mg, Si, Fe, and Cu) from American Smelting and Refining Co. and 99.99+ pure Pd sponge (with no Fe impurity) from Engelhard Industries Inc. melted together in high-purity recrystallized alumina crucible by induction heating in Ar, molded into slugs, etched, homogenized in Ar for 7.7d at 1123 K, slowly cooled, swaged to smaller diam and drawn down to final diam with intermediate anneals in Ar at 973 and 723 K, and finally annealed in vacuum of 10^{-6} mm Hg at 973 K for 24 h; uncertainty in temperature 0.01 K above 16 K and 0.1 K below 16 K, temperature controlled to within 0.01 K, uncertainty in resistivity of about 1%; data extracted from table.
2	279	Hau, N.H.	1966	A	4.2-298	A15		24.265	Calculated composition (14.754 a/o Au); similar to the above specimen but with lattice parameter of 3.9168 Å.
3	279	Hau, N.H.	1966	A	4.2-298	A35		49.999	Calculated composition (35.072 a/o Au); similar to the above specimen but with lattice parameter of 3.9549 Å.
4	131	Röhl, H.	1933		90-413	AP5	56.0		Calculated composition (70.2 a/o Pd); homogenized 2 h at 1073 K, heat treated 2 h at 1073 K and 10 h at 573 K; data extracted from table.
5	131	Röhl, H.	1933		90-413	AP6	70.0		Calculated composition (81.2 a/o Pd); similar to the above specimen.
6	131	Röhl, H.	1933		90-413	AP7	85.0		Calculated composition (91.3 a/o Pd); similar to the above specimen.
7	131	Röhl, H.	1933		273	AP9	50.1		Calculated composition (65.0 a/o Pd); similar to the above specimen.
8	131	Röhl, H.	1933		273	AP10	61.8		Calculated composition (75.0 a/o Pd); similar to the above specimen.
9	131	Röhl, H.	1933		273	AP11	76.8		Calculated composition (86.0 a/o Pd); similar to the above specimen.
10	280	Conybeare, J.G.G.	1937	V	90-1250			38.2	Calculated composition (25 a/o Au); rod 2 mm in diam and 12 cm long obtained from Johnson Matthey and Co.; annealed until resistance became constant; considerable increase in specific resistance upon annealing was attributed to growth of fairly large crystals (observed microscopically) with small fissures between them; measured under vacuum of less than 10^{-6} mm Hg except at highest temperatures where pressure increased to 10^{-4} mm Hg due to evolution of gas; resistance ratio R_T/R_{273} and resistivity at 273 K were extracted from table and converted by CINDAS to resistivity without correcting for thermal expansion; resistance ratios were reproducible to 0.1%.
11	284	Köster, W. and Hagmann, D.	1961		293			3.63	Calculated composition (2 a/o Au); 0.1 mm diam wire specimen supplied by Fa. Degussa; annealed at 1073 K for 1 h and furnace-cooled; data extracted from table, reported data were multiplied by 10 to account for incorrect placement of the decimal in the table; measurement temperature not stated explicitly, assumed to be 293 K.
12	284	Köster, W. and Hagmann, D.	1961		293			7.07	Calculated composition (4 a/o Au); similar to the above specimen.

TABLE 46. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + GOLD ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Pd	Au	Composition (continued), Specifications, and Remarks
13	276	Rowland, T., Cusack, N.E., and Ross, R.G.	1974	A	4-1400			16.0	Calculated composition (9.3 a/o Au), concentration of main components measured to ± 0.3 a/o by chemical and x-ray analysis, spectrographic analysis revealed major trace impurities of 10 ppm Fe and 10 ppm Ag; wire specimen between 0.31 and 0.38 mm in diam prepared by author at Johnson Matthey and Co. Ltd. from sponges of spectroscopically pure Pd and 99.999 pure Au by pressing sponge into bars, sintering in vacuum at 1173 K for several hours, induction melting in stream of pure argon, cold-rolling ingots to 3 mm square rods, and by finally drawing down to final diam; annealed at 1073 K in vacuum for a few hours and slowly furnace cooled; residual resistivity ratio, $\rho_{4.2}/\rho_{273}$ = 0.4106; ± 5% uncertainty in resistivity, due mainly to uncertain diam; data from tables supplied by author in private communication.
14	276	Rowland, T., et al.	1974	A	4-1400			31.0	Calculated composition (19.5 a/o Au); similar to the above specimen but with major trace impurities of 20 ppm Ag and 30 ppm Fe and $\rho_{4.2}/\rho_{273}$ = 0.6128.
15	276	Rowland, T., et al.	1974	A	4-1400			44.8	Calculated composition (30.5 a/o Au); similar to the above specimen but with major trace impurities of 20 ppm Fe and 40 ppm Ag and $\rho_{4.2}/\rho_{273}$ = 0.7351.

TABLE 47. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + GOLD ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega m$]

T	ρ
DATA SET 1	
4.2	5.480
77.3	5.205
298	13.93
DATA SET 2	
4.2	9.860
77.3	11.46
298	19.33
DATA SET 3	
4.2	21.50
77.3	22.64
298	27.76
DATA SET 4	
90.2	20.9
194.7	24.0
273.2	26.0
373.2	29.4
413.2	30.7
DATA SET 5	
90.2	14.6
194.7	18.4
273.2	21.3
373.2	25.0
413.2	26.5
DATA SET 6	
90.2	8.83
194.7	13.4
273.2	16.1
373.2	20.4
413.2	22.1
DATA SET 7	
273.2	27.7
DATA SET 8	
273.2	24.4
DATA SET 9	
273.2	19.5
DATA SET 10	
90.2	23.4
273.2	28.7
373	31.1
473	33.4
573	35.5
673	37.3
773	38.9
873	40.6
973	42.2
1073	43.8
1173	45.5
1250	46.8
DATA SET 11	
293	12.3
DATA SET 12	
293	13.4
DATA SET 13	
4	6.68
50	7.35
90	8.95
200	13.45
300	17.25
500	23.90
600	27.00
700	29.78
800	32.32
900	34.60
1000	36.85
1100	39.10
1200	41.10
1300	42.90
1400	44.70
DATA SET 14	
4	13.15
50	13.75
90	15.13
200	19.05
300	22.30
500	28.20
600	30.65
700	32.79
800	34.85
900	36.60
1000	38.40
1100	39.98
1200	41.66
1300	43.10
1400	44.60*
DATA SET 15	
4	19.58
50	20.00
90	20.93*
200	24.05
300	26.60
500	30.60
600	32.28
700	33.78
800	35.00
900	36.50*
1000	37.40
1100	38.60
1200	39.80
1300	42.50*
1400	43.00

* Not shown in figure.

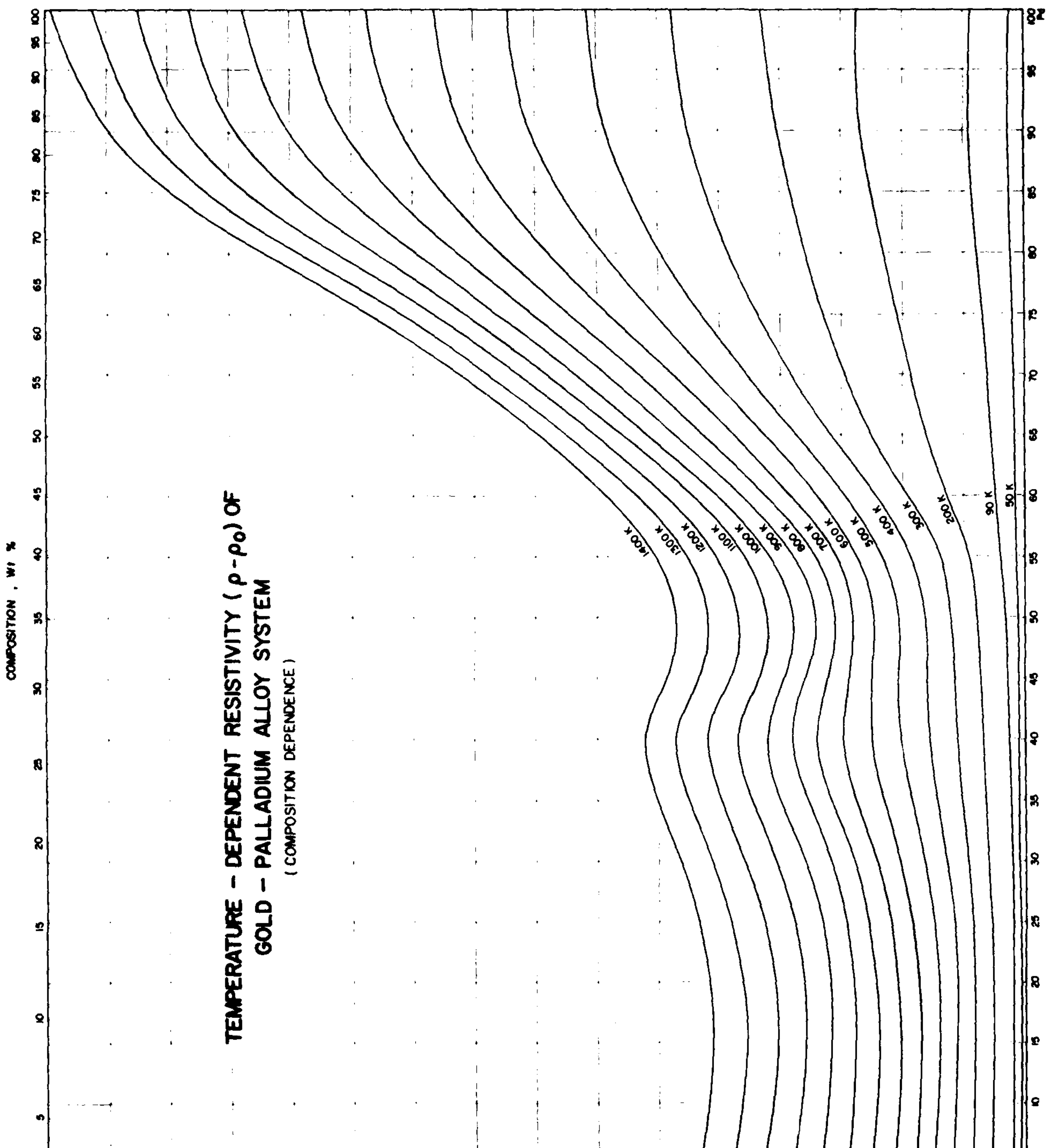

TEMPERATURE - DEPENDENT RESISTIVITY (ρ - ρo) OF
GOLD - PALLADIUM ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION , Wt %
COMPOSITION , At. %
TEMPERATURE - DEPENDENT RESISTIVITY, 10⁻⁸ Ω m
CINDAS
Au
Pd
1400 K
1300 K
1200 K
1100 K
1000 K
900 K
800 K
700 K
600 K
500 K
400 K
300 K
200 K
90 K
50 K

FIGURE 39

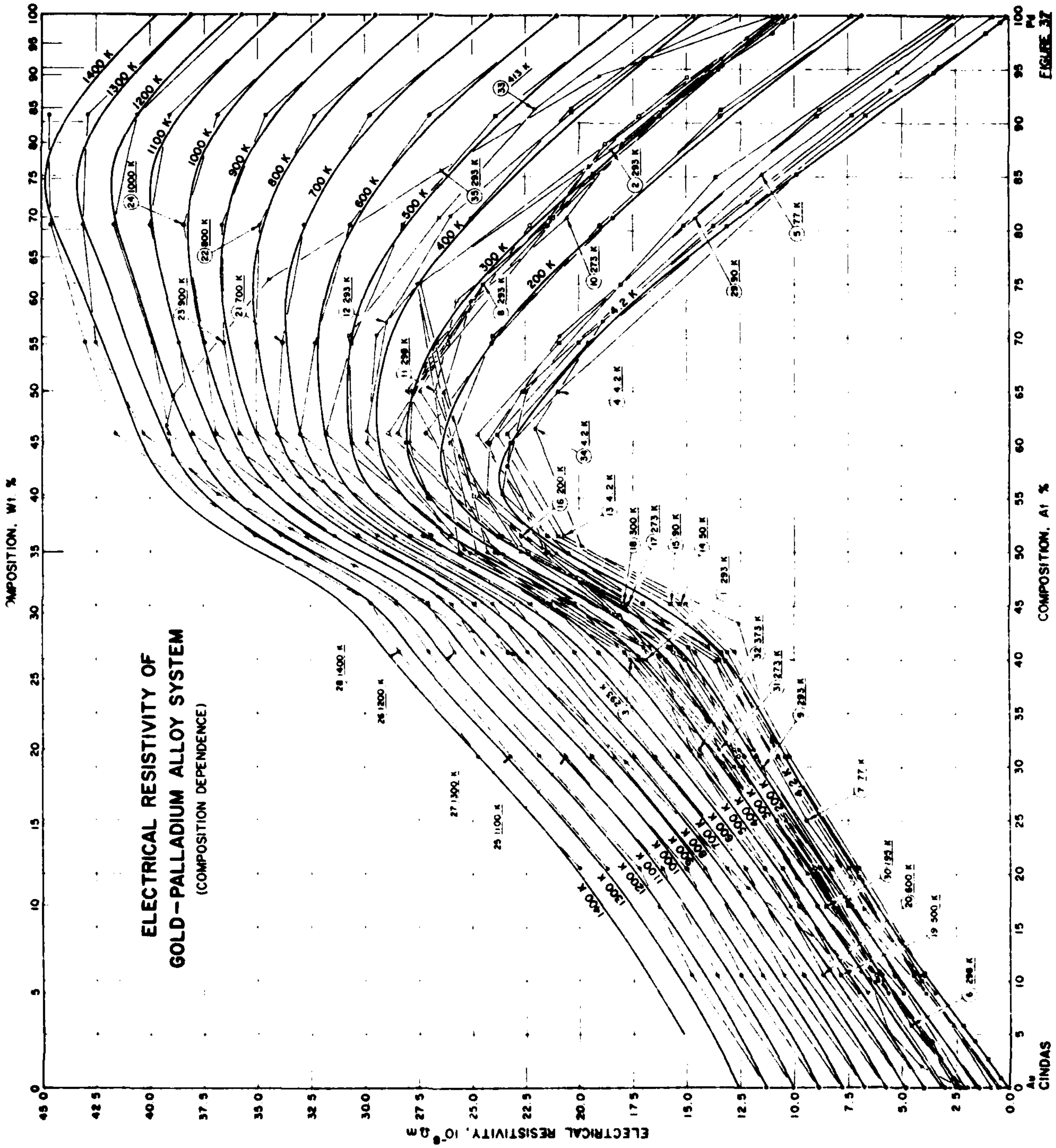

ELECTRICAL RESISTIVITY OF
GOLD-PALLADIUM ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION, Wt %
COMPOSITION, At %
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
Au
Pd
CINDAS
FIGURE 37

TABLE 48. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM (Composition Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At. % of Pd)	Composition (weight percent), Specifications, and Remarks
1	271	Köster, W. and Halpern, T.	1961		293	0-100	99.95 pure Pd and 99.99 pure Au from Fa. Degussa Hanau melted together, homogenized in vacuum at 1073 to 1223 K for 70 h and furnace-cooled; reduced 98.5% by cold-rolling from a thickness of 7 mm to 0.1 mm without intermediate annealing; measurement temperature not stated explicitly, assumed to be 293 K; data extracted from table.
2	271	Köster, W. and Halpern, T.	1961		293	0-100	The above specimens annealed at 973 K and quenched in water.
3	271	Köster, W. and Halpern, T.	1961		293	20-75	The above specimens annealed at 1073 K and cooled slowly in furnace.
4	279	Hau, N.H.	1966	A	4.2	0-100	Compositions determined by weight and lattice parameter; 0.07 mm in diam and about 16 cm long; 99.999+ pure Au splatters (0.0002 Ag, <0.0001 Mg, Si, Fe, and Cu) from American Smelting and Refining Co. and 99.99+ pure Pd sponge (with no Fe impurity) from Engelhard Industries, Inc. melted together in high-purity recrystallized alumina crucibles by induction heating in Ar, molded into slugs, etched, homogenized in Ar for about 7 d at 1123 K, slowly cooled, swaged to smaller diam and drawn down to final diam with intermediate anneals at 723 and 973 K, and finally annealed in vacuum of 10^{-5} mm Hg at 973 K for 24 h; uncertainty in temperature 0.1 K, temperature controlled to within 0.01 K, uncertainty in resistivity of about 1%; data extracted from table.
5	279	Hau, N.H.	1966	A	77.3	0-100	The above specimens; uncertainty in temperature 0.01 K at this higher temperature.
6	279	Hau, N.H.	1966	A	298	0-100	The above specimens.
7	272	Logie, H.J., Jackson, J., Anderson, J.C., and Nabarro, F.R.N.	1961	A	77.4	0-100	Polycrystalline wire specimens 0.2 mm in diam and 100 mm long; 99.998+ pure Au and Pd melted together in vacuum, drawn to final diam, annealed at 1173 K for 3 h, and furnace cooled; measured at liquid nitrogen temperature; authors observed small but distinct discontinuity in the slope of the curve at 40 a/o Pd; data read from figure.
8	232	Kim, M.J. and Flanagan, W.F.	1967	P	293	10-95	Clover shaped, polycrystalline foil specimens; 100 mesh powders of 99.99 pure Au and 99.97 pure Pd from Englehard Industries Inc. melted together in high purity alumina crucibles by induction heating under a vacuum of 10^{-5} to 10^{-6} Torr; homogenized for 1 week at 1173 K in vacuum of 10^{-5} to 10^{-6} Torr and surface of ingot ground off to eliminate concentration gradients; specimens, as annealed, were measured in a room temperature silicone oil bath; data read from figure.
9	232	Kim, M.J. and Flanagan, W.F.	1967	P	293	10-95	The above specimens measured after 40% reduction in area.
10	285	Geibel, W.	1911		273	0-100	Specimens 0.1 mm in diam and 50 cm long; supplied by Firma Heraeus; measured at room temperature and corrected to 273 K; data extracted from table.
11	286	Schulze, F.A.	1911		298	17-94	Specimens 1 mm in diam supplied by Firma Heraeus; data extracted from table.
12	287	Rudnitskii, A.A.	1956		293	0-100	Survey report, no measurement information given; measurement temperature not stated explicitly, assumed to be 293 K; data read from figure.

TABLE 48. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Pd)	Composition (weight percent), Specifications, and Remarks
13	276	Rowland, T., Cusack, N.E., and Ross, R.G.	1974	A	4.2	0-100	Details of preparation and characterization of the concentrated specimens given in preceding tables (Au + Pd *data sets 26-32 and* Pd + Au *data sets 13-15*); the pure metals and dilute alloys (0.09-4.33 a/o Pd and 95.34-99.88 a/o Pd) were prepared by a similar method by Johnson Matthey and Co. Ltd.; spectrographic analysis of the 0, 0.09, 0.51, 0.91, 2.70, 4.33, 95.34, 98.48, 99.43, 99.88, and 100 a/o Pd specimens showed the following respective impurities (ppm): 2 Fe, 3 Ag; 10 Al, 10 Fe, 10 Si, 30 Cu; 10 Fe, 20 Si, 30 Al, 30 Cu; 10 Fe, 10 Si, 30 Al, 30 Cu; 10 Si, 20 Pt, 30 Al, 30 Cu; 10 Pt, 10 Si, 20 Al, 30 Cu; 10 Ag, 30 Fe, 50 Pt; 10 Ag, 20 Fe, 30 Pt; 10 Ag, 10 Pt; 10 Ag, 10 Fe, 10 Pt; 1 Fe, 10 Pt; solute concentrations of the dilute alloys accurate to within ± 0.05 a/o; annealed at 1073 K in vacuum for a few hours and slowly furnace cooled; ± 5% uncertainty in resistivity due mainly to uncertain diam; data extracted from table.
14	276	Rowland, T., et al.	1974	A	50	10.5-100	The above specimens.
15	276	Rowland, T., et al.	1974	A	90	0-100	The above specimens.
16	276	Rowland, T., et al.	1974	A	200	0-100	The above specimens.
17	276	Rowland, T., et al.	1974	A	273	0-100	The above specimens.
18	276	Rowland, T., et al.	1974	A	300	0-100	The above specimens.
19	276	Rowland, T., et al.	1974	A	500	0-100	The above specimens.
20	276	Rowland, T., et al.	1974	A	600	0-100	The above specimens.
21	276	Rowland, T., et al.	1974	A	700	0-100	The above specimens.
22	276	Rowland, T., et al.	1974	A	800	0-100	The above specimens.
23	276	Rowland, T., et al.	1974	A	900	0-100	The above specimens.
24	276	Rowland, T., et al.	1974	A	1000	0-100	The above specimens.
25	276	Rowland, T., et al.	1974	A	1100	0-100	The above specimens.
26	276	Rowland, T., et al.	1974	A	1200	0-100	The above specimens.
27	276	Rowland, T., et al.	1974	A	1300	20.5-100	The above specimens.
28	276	Rowland, T., et al.	1974	A	1400	20.5-90.7	The above specimens.
29	131	Röhl, H.	1933		90.2	8.86-100	Homogenized at 1073 K for 2 h, heat-treated at 1073 K for 2 h and at 573 K for 10 h; data extracted from table.
30	131	Röhl, H.	1933		194.7	8.86-100	The above specimens.
31	131	Röhl, H.	1933		273.2	8.86-100	The above specimens.
32	131	Röhl, H.	1933		373.2	8.86-100	The above specimens.
33	131	Röhl, H.	1933		413.2	8.86-100	The above specimens.
34	277	Kim, M.J.	1966		4.2	8.6-93.0	Original document unavailable; residual resistivity values as reported by Kim, M.J. and Flanagan, W.F. [Acta Met., 15(5), 747-52, 1967] without measurement information; measurement temperature assumed to be 4.2 K, although not stated explicitly; data read from figure.
35	288	Borelius, G.	1925		293	0-100	Survey reported resistivity without measurement information; measurement temperature assumed to be 293 K although not stated explicitly; data read from figure.

TABLE 49. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM (Composition Dependence)

[Composition, C, a/o Pd; Electrical Resistivity, ρ, $10^{-8}\ \Omega m$]

DATA SET 1 (T = 293 K)

C	ρ
0	2.50
20	9.1
30	12.5
40	16.9
50	24.3
75	27.4
100	10.82

DATA SET 2 (T = 293 K)

C	ρ
0	2.41
20	9.2
30	12.8
40	17.1
50	24.8
75	27.5
87.5	18.5
96	13.4
98	12.2
100	10.80*

DATA SET 3 (T = 293 K)

C	ρ
20	9.4
30	13.2
40	17.6
50	25.6
75	27.5*

DATA SET 4 (T = 4.2 K)

C	ρ
0	0.0075
5.83	2.182
10.77	3.993
19.70	7.041
39.98	13.20
49.85	20.51
55.41	23.57
60.14	23.19
64.93	21.50
85.25	9.860
94.79	3.480

DATA SET 4 (cont.) (T = 4.2 K)

C	ρ
100	0.1422*
100	0.1117

DATA SET 5 (T = 77.3 K)

C	ρ
0	0.444
5.83	2.626
10.77	4.411
19.70	7.439
39.98	13.65
49.85	21.09
55.41	24.29
60.14	24.16
64.93	22.64
85.25	11.46
94.79	5.205
100	2.284*
100	2.152

DATA SET 6 (T = 298 K)

C	ρ
0	2.235
5.83	4.350
10.77	6.069
19.70	9.124
39.98	15.94
49.85	23.56
55.41	27.09
60.14	28.06
64.93	27.76
85.25	19.33
94.79	13.93
100	10.78*
100	10.73

DATA SET 7 (T = 77.4 K)

C	ρ
0	0.84
10	4.10
25	9.42
40	13.48
50	21.47

DATA SET 7 (cont.) (T = 77.4 K)

C	ρ
58	23.34
65	22.49
75	18.05
85	13.64
100	2.83

DATA SET 8 (T = 293 K)

C	ρ
10	6.12
25	10.82
30	12.40
40	15.96
50	23.93
65	28.00
75	24.46
85	19.37
95	13.54

DATA SET 9 (T = 293 K)

C	ρ
10	5.90
25	10.40
30	11.48
40	15.07
50	22.72
65	27.40
75	24.46*
85	19.37*
95	13.81*

DATA SET 10 (T = 273.2 K)

C	ρ
0	2.10
17.0	7.37
31.6	12.59
44.2	18.08
55.2	24.69
64.9	26.32
73.5	25.25
81.2	20.58
88.1	18.02
94.33	14.27
100	10.56

DATA SET 11 (T = 298 K)

C	ρ
17.0	7.54
31.6	12.8
44.2	18.3
55.2	24.9
64.9	26.7
73.5	25.7
81.2	21.2
88.1	18.8
94.3	15.0

DATA SET 12 (T = 293 K)

C	ρ
0	3.0
9.8	6.3
19.6	9.9
30.3	13.3
40.0	17.3
50.3	25.4
61.2	29.9
71.4	29.0
81.4	26.0
91.0	20.4
96.1	17.0
100	12.7

DATA SET 13 (T = 4.2 K)

C	ρ
0	0.006*
0.09	0.033*
0.51	0.169
0.91	0.402
2.70	1.023
4.33	1.680
10.5	3.96
20.5	7.01
31.0	10.20
40.7	12.76
45.2	15.07
51.5	20.72
61.0	23.38
69.5	19.58
80.5	13.15
90.7	6.68

DATA SET 13 (cont.) (T = 4.2 K)

C	ρ
95.34	3.249
98.48	1.059
99.43	0.420
99.88	0.115*
100	0.022*

DATA SET 14 (T = 50 K)

C	ρ
10.5	4.18
20.5	7.18
31.0	10.40
40.7	13.10
45.2	15.32
51.5	21.00
61.0	23.80
69.5	20.00
80.5	13.75
90.7	7.35
100	0.72

DATA SET 15 (T = 90 K)

C	ρ
0	0.54
10.5	4.47
20.5	7.49
31.0	10.72
40.7	13.40
45.2	15.75
51.5	21.49
61.0	24.75
69.5	20.93
80.5	15.13
90.7	8.95
100	2.19*

DATA SET 16 (T = 200 K)

C	ρ
0	1.40
10.5	5.37
20.5	8.30
31.0	11.75
40.7	14.60

DATA SET 16 (cont.) (T = 200 K)

C	ρ
45.2	17.05
51.5	22.72
61.0	27.15
69.5	24.05
80.5	19.05
90.7	13.45
100	6.85

DATA SET 17 (T = 273 K)

C	ρ
0	2.00
0.09	2.04
0.51	2.35
0.91	2.59
2.70	3.22
4.33	3.62
10.5	5.99
20.5	8.85
31.0	12.33
40.7	15.34
45.2	17.78
51.5	23.60
61.0	28.48
69.5	26.64
80.5	21.46
90.7	16.27
95.34	13.31
98.48	11.00
99.43	10.52
99.88	9.75*
100	9.95

DATA SET 18 (T = 300 K)

C	ρ
0	2.25*
10.5	6.22
20.5	9.05
31.0	12.60
40.7	15.60
45.2	17.95
51.5	23.78
61.0	28.90
69.5	26.60

* Not shown in figure.

TABLE 49. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD-PALLADIUM ALLOY SYSTEM (Composition Dependence) (continued)

DATA SET 18 (cont.) (T = 300 K)

C	ρ
80.5	22.30
90.7	17.25
100	10.80*

DATA SET 19 (T = 500 K)

C	ρ
0	3.97
10.5	7.85
20.5	10.57
31.0	14.42
40.7	17.88
45.2	20.22
51.5	26.02
61.0	31.80
69.5	30.60
80.5	28.20
90.7	23.90
100	17.39

DATA SET 20 (T = 600 K)

C	ρ
0	4.83
10.5	8.70
20.5	11.40
31.0	15.40
40.7	19.10
45.2	21.35
51.5	27.30
51.5	26.90
61.0	33.00
69.5	32.28
80.5	30.65
90.7	27.00
100	21.07

DATA SET 21 (T = 700 K)

C	ρ
0	5.79
10.5	9.60
20.5	12.28
31.0	16.47
40.7	20.21
45.2	22.26
51.5	27.85

DATA SET 21 (cont.) (T = 700 K)

C	ρ
61.0	34.05
69.5	33.78
80.5	32.79
90.7	29.78
100	24.09

DATA SET 22 (T = 800 K)

C	ρ
0	6.76
10.5	10.50
20.5	13.15
31.0	17.40
40.7	21.20
45.2	23.05
51.5	28.60
61.0	35.00
69.5	35.00
80.5	34.85
90.7	32.32
100	26.89

DATA SET 23 (T = 900 K)

C	ρ
0	7.79
10.5	11.50
20.5	14.40
31.0	18.30
40.7	22.40
45.2	24.00
51.5	[illegible]
61.0	35.80
69.5	36.50
80.5	36.60
90.7	34.60
100	29.50

DATA SET 24 (T = 1000 K)

C	ρ
0	8.89
10.5	12.50
20.5	15.00
31.0	19.40
40.7	23.30
45.2	24.86

DATA SET 24 (cont.) (T = 1000 K)

C	ρ
51.5	30.30
61.0	36.90
69.5	37.40
80.5	38.40
90.7	36.85
100	31.92

DATA SET 25 (T = 1100 K)

C	ρ
0	10.06
10.5	13.60
20.5	16.10
31.0	20.60
40.7	24.50
45.2	25.90
51.5	31.40
61.0	38.00
69.5	38.60
80.5	39.98
90.7	39.10
100	34.20

DATA SET 26 (T = 1200 K)

C	ρ
0	11.32
10.5	14.80
20.5	17.23
31.0	21.88
40.7	25.80
45.2	27.04
51.5	32.65
61.0	39.10
69.5	39.80
80.5	41.66
90.7	41.10
100	36.21

DATA SET 27 (T = 1300 K)

C	ρ
20.5	18.70
31.0	23.20
40.7	27.00
45.2	28.50
51.5	33.90

DATA SET 27 (cont.) (T = 1300 K)

C	ρ
61.0	40.30
69.5	42.50
80.5	43.10
90.7	42.90
100	38.09

DATA SET 28 (T = 1400 K)

C	ρ
20.5	20.00
31.0	24.70
40.7	28.40
45.2	29.70
51.5	35.10
61.0	41.60
69.5	43.00
80.5	44.60
90.7	44.70

DATA SET 29 (T = 90.2 K)

C	ρ
8.86	3.90
17.0	7.41
31.6	11.9
41.2	14.0
49.9	21.5
60.2	24.3
70.2	20.9
81.2	14.6
91.3	8.83
100	2.62

DATA SET 30 (T = 194.7 K)

C	ρ
8.86	4.91
17.0	8.57
31.6	12.8
41.2	14.9
49.9	22.4
60.2	26.0
70.2	24.0
81.2	18.4
91.3	13.4
100	7.32

DATA SET 31 (T = 273.2 K)

C	ρ
8.86	5.65
17.0	8.97
31.6	13.5
41.2	15.7
49.9	23.8
55.0	27.1
60.2	27.9
65.0	27.7
70.2	26.0
75.0	24.4
81.2	21.3
86.0	19.5
91.3	16.1
100	10.3

DATA SET 32 (T = 373.2 K)

C	ρ
8.86	6.64
17.0	9.83
31.6	14.4
41.2	16.7
49.9	25.1
60.2	29.9
70.2	29.4
81.2	25.0
91.3	20.4
100	14.7

DATA SET 33 (T = 413.2 K)

C	ρ
8.86	7.02
17.0	10.2
31.6	14.8
41.2	17.0
49.9	25.5
60.2	30.6
70.2	30.7
81.2	26.5
91.3	22.1
100	16.4

DATA SET 34 (T = 4.2 K)

C	ρ
8.6	3.55

DATA SET 34 (cont.) (T = 4.2 K)

C	ρ
16.7	6.77
32.4	11.02
43.4	12.55
50.6	19.99
61.5	22.04
71.6	18.87
82.7	12.15
93.0	5.53

DATA SET 35 (T = 293 K)

C	ρ
0.0	2.2
2.2	4.1
5.3	5.7
10.1	6.5
18.7	12.2
30.5	17.8
40.6	23.1
48.8	30.5
50.2	32.8
52.2	33.4
55.4	36.8
59.1	38.9
61.8	39.2
64.6	38.9
75.4	34.4
85.6	26.4
94.3	19.1
100.0	11.0

* Not shown in figure.

3.8. Gold-Silver Alloy System

Most of the evidence [264,289] indicates that the gold-silver alloy system forms a continuous series of solid solutions. Grum-Grzhimailo [290] has reported measurements on the electrical resistance, Hall effect, and lattice parameter which indicate the formation of intermetallic compounds Ag_3Au, Ag_3Au_3, and $AgAu_3$, but this work has been discounted in the present analysis.

The existence of short-range ordering in the gold-silver alloy system is well recognized, though the mechanism of the ordering process and the effects of short-range order on the resistivity are disputed. Lücke and co-workers [291-293,275] have performed isothermal and isochronal annealing investigations of a wide range of silver-gold alloys and have concluded that an increase in the degree of short-range order is associated with an increase in the electrical resistivity and that the short-range order is of the conventional type described by Cowley [294]. On the contrary, Schüle and co-workers [295,296] have reported measurements on specimens very nearly identical with those of Lücke et al. which indicate that an increase in the degree of short-range order is associated with a decrease in the electrical resistivity under certain conditions and that the formation of short-range order proceeds in a non-homogeneous manner via the growth of localized regions of high order, the boundaries of which can cause additional electron scattering and the consequent resistivity increase observed by Lücke et al. The change in the resistivity of quenched gold-silver alloy specimens upon annealing and the formation of short-range order can be as much as 2%.

There are 183 sets of experimental data available for the electrical resistivity of this alloy system, with 17 sets being single data points. These data sets are listed in tables 51, 53, and 55 which provide information on specimen characterization and measurement conditions, tabulated in tables 52, 54, and 56, and shown partially in figures 40, 41, and 42. In order to show both functional dependences of the electrical resistivity, a few of the data sets have been presented in the tables and figures both for temperature dependence and for composition dependence.

In the analysis and synthesis of experimental data to generate recommended values, the dependence of residual resistivity on alloy composition was determined using the abundant data from measurements at 4.2 K and below. A curve

representing the totality of the data was tested and smoothed by examination of second differences. It shows a region of relatively low curvature for atomic fractions c of silver between 0.65 and 0.85 (between 65 and 85 at.% Ag); the reality of this feature seems to be supported by analysis of the alloy resistivities at higher temperatures.

The analysis of alloy resistivity was based on a study of the quantity $\Delta(c,T)$, as given by eq (26), derived from total resistivity values by subtracting from them the residual resistivity for the given c and the atomic-fraction-weighted average of the pure metal resistivities for the given T. The quantity Δ is only a few percent of the total resistivity, and varies smoothly with c except for very dilute alloys. The analysis is described in some detail in Appendix 5.1; here a very few comments will suffice.

Examination of Δ values makes very evident the presence of relatively large and erratic errors in much of the older data, probably due to inadequate control of the composition and purity of the alloy samples. The analysis began with a study of the data for $T < 300$ K obtained using samples for which the resistivity was also measured at 4.2 K or below, since knowledge of the latter quantity helped to eliminate or diminish several sources of error. The data of Giauque and Stout [297] (Au + Ag data sets 23-26, Ag + Au data sets 21, 22, and Au-Ag data sets 16-20), Crisp and Rungis [298] (Au + Ag data sets 38-44, Ag + Au data sets 30-39, and Au-Ag data sets 9, 10), Davis and Rayne [299] (Au + Ag data sets 51-57, Ag + Au data sets 48-51, and Au-Ag data sets 11-13), Boes et al. [300] (Au + Ag data sets 6-11, Ag + Au data sets 5-10, and Au-Ag data sets 2, 3), and Huray et al. [135] (Au + Ag data sets 45, 46 and Ag + Au data sets 40, 41) were plotted and cross-plotted to arrive at acceptable smoothed values of Δ and Δ/T from 100 K to 300 K. The values of Δ could be extrapolated to lower temperatures and to more dilute alloys guided by values derived from the data of Stewart and Huebener [301] (Au + Ag data sets 58-60 and Au-Ag data set 14) and of Dugdale and Basinski [29] (Au-Ag data set 15), who studied deviations from Matthiessen's Rule in alloys with less than 1 at.% solute. The analysis was then extended to higher temperatures by using the data of Iyer and Asimow [302] (Au + Ag data sets 2-5, Ag + Au data sets 11-13, and Au-Ag data set 46) on alloys with 5, 10, 30, 50, 70, 90 and 95 at.% silver. These data were smoothed and then partially corrected for errors that have a systematic effect on a plot of Δ against T for a single sample (errors in

solute concentration, in sample dimensions, and in the residual resistivity curve) by comparison with the more accurate low-temperature data. The reasonableness of the corrections was checked, and the values were interpolated and extrapolated to other solute concentrations by use of cross-plots. Finally, the recommended values of the resistivity were derived from the values of Δ, ρ_0, and the pure-metal resistivities.

The most reliable results were obtained for concentrated alloys (20 to 80 at.% solute), for which extrapolation of Δ to low temperature and of Δ/T to high temperatures was most reliable. At low temperatures and low solute concentrations the uncertainty (in percent) rises along with the estimated uncertainty in the residual resistance. At high temperatures and low solute concentrations the uncertainty in the extrapolation of Δ combines with the uncertainty in the resistivity of the pure metals to produce the estimated ±4% uncertainty in the result. It is unfortunate that there seem to be no resistivity data on Ag-Au alloys with less than 5 at.% of solute, for $T >$ 400 K.

The resulting recommended electrical resistivity values for Au, Ag, and for 25 Au-Ag binary alloys are presented in table 50 and shown in figures 38, 39, and 42. The recommended values for Au and for Ag are for well-annealed high-purity specimens, but those values for temperatures below about 100 K are applicable only to Au and Ag having residual electrical resistivities as given at 1 K in table 50. As discussed in the beginning of this section, the electrical resistivity of Au-Ag alloys can be varied by changes in their short-range order produced by thermal treatment. This can amount to as much as 2% in the case of concentrated alloys subjected to extremes of quenching and annealing. The data analyzed here were obtained with samples not deliberately subjected to such treatment, and the recommended values may be regarded as applicable to alloys which have not been quenched or cold-worked severely and have the equilibrium degree of short-range order at each temperature. The recommended values cover the temperature range from 1 K to 1200 K and are not corrected for the thermal expansion of the material. The estimated uncertainties in the values for the various alloys and for different temperature ranges are explicitly stated in a footnote to table 50.

TABLE 50. RECOMMENDED ELECTRICAL RESISTIVITY OF GOLD-SILVER ALLOY SYSTEM†

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Au: 100.00% (100.00 At.%) Ag: 0.00% (0.00 At.%)		Au: 99.50% (99.09 At.%) Ag: 0.50% (0.91 At.%)		Au: 99.00% (98.19 At.%) Ag: 1.00% (1.81 At.%)		Au: 97.00% (94.65 At.%) Ag: 3.00% (5.35 At.%)		Au: 95.00% (91.23 At.%) Ag: 5.00% (8.77 At.%)		Au: 90.00% (83.13 At.%) Ag: 10.00% (16.87 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	0.0220	1	0.272*	1	0.536*	1	1.55*	1	2.47*	1	4.48*
4	0.0220	4	0.272	4	0.536	4	1.55	4	2.47	4	4.48
7	0.0221	7	0.272*	7	0.537	7	1.55	7	2.48	7	4.48
10	0.0226	10	0.274*	10	0.539	10	1.55	10	2.48	10	4.49
15	0.0258	15	0.280*	15	0.545	15	1.55	15	2.48	15	4.49
20	0.0346‡	20	0.292	20	0.557	20	1.57	20	2.50	20	4.50
25	0.0503‡	25	0.312	25	0.577	25	1.59	25	2.52	25	4.52
30	0.0727‡	30	0.340	30	0.606	30	1.61	30	2.54	30	4.55
40	0.141‡	40	0.414	40	0.681	40	1.69	40	2.62	40	4.62
50	0.222	50	0.498	50	0.766	50	1.78	50	2.70	50	4.71
60	0.309	60	0.583	60	0.855	60	1.87	60	2.80	60	4.80
70	0.396	70	0.669	70	0.944	70	1.96	70	2.89	70	4.89
80	0.482	80	0.754	80	1.03	80	2.05	80	2.98	80	4.98
90	0.567	90	0.838	90	1.12	90	2.14	90	3.07	90	5.07
100	0.652	100	0.921	100	1.20	100	2.23	100	3.16	100	5.16
150	1.063	150	1.33	150	1.61	150	2.66	150	3.60	150	5.59
200	1.464	200	1.73	200	2.00	200	3.07	200	4.00	200	5.99
250	1.865	250	2.13	250	2.40	250	3.46	250	4.40	250	6.39
273	2.052	273	2.31	273	2.58	273	3.64	273	4.58	273	6.57
293	2.214	293	2.47	293	2.75	293	3.80	293	4.74	293	6.73
300	2.271	300	2.53*	300	2.80*	300	3.86	300	4.79	300	6.78
350	2.683	350	2.94*	350	3.22*	350	4.26	350	5.19	350	7.19
400	3.102	400	3.36*	400	3.63*	400	4.66	400	5.59	400	7.55
500	3.962	500	4.21*	500	4.47*	500	5.48	500	6.40	500	8.39
600	4.853	600	5.08*	600	5.33*	600	6.32	600	7.25	600	9.23
700	5.780	700	5.99*	700	6.23*	700	7.20	700	8.14	700	10.12
800	6.755	800	6.94*	800	7.16*	800	8.13	800	9.09	800	11.06
900	7.787	900	7.95*	900	8.16*	900	9.13	900	10.09	900	12.05
1000	8.884	1000	9.04*	1000	9.24*	1000	10.20	1000	11.16	1000	13.10
1100	10.057	1100	10.19*	1100	10.39*	1100	11.33*	1100	12.30	1100	14.22
1200	11.312	1200	11.43*	1200	11.61*	1200	12.55*	1200	13.52	1200	15.42
1300	12.632										
1337.58	13.146 (s)										
1338	31.08 (ℓ)										
1700	36.26										

† Uncertainties in the electrical resistivity values are as follows:

100.00 Au – 0.00 Ag: ±1% up to 10 K, ±2.5% above 10 K to 15 K, ±6% above 15 K to 40 K, ±3% above 40 K to 80 K, ±1% above 80 K to 500 K, and ±2.5% above 500 K.
99.50 Au – 0.50 Ag: ±4% below 80 K, ±3% from 80 to 600 K, and ±4% above 600 K.
99.00 Au – 1.00 Ag: ±4% below 80 K, ±3% from 80 to 600 K, and ±4% above 600 K.
97.00 Au – 3.00 Ag: ±4% below 80 K, ±3% from 80 to 400 K, and ±2% above 400 K.
95.00 Au – 5.00 Ag: ±2% up to 600 K and ±1% above 600 K.
90.00 Au – 10.00 Ag: ±1%.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 50. RECOMMENDED ELECTRICAL RESISTIVITY OF GOLD-SILVER ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Au: 85.00% (75.63 At.%) Ag: 15.00% (24.37 At.%)		Au: 80.00% (68.66 At.%) Ag: 20.00% (31.34 At.%)		Au: 75.00% (62.16 At.%) Ag: 25.00% (37.84 At.%)		Au: 70.00% (56.10 At.%) Ag: 30.00% (43.90 At.%)		Au: 65.00% (50.42 At.%) Ag: 35.00% (49.58 At.%)		Au: 60.00% (45.10 At.%) Ag: 40.00% (54.90 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	6.08*	1	7.30*	1	8.18*	1	8.73*	1	9.00*	1	9.01*
4	6.08	4	7.30	4	8.18	4	8.73*	4	9.00*	4	9.01*
7	6.08	7	7.30	7	8.18*	7	8.73*	7	9.00	7	9.01*
10	6.09	10	7.31	10	8.18*	10	8.73*	10	9.00	10	9.01*
15	6.09	15	7.31	15	8.18*	15	8.74*	15	9.00	15	9.02*
20	6.10	20	7.32	20	8.19*	20	8.75*	20	9.01	20	9.03*
25	6.12	25	7.34	25	8.21*	25	8.76*	25	9.03	25	9.04*
30	6.15	30	7.36	30	8.23*	30	8.78*	30	9.05	30	9.06*
40	6.22	40	7.43	40	8.30*	40	8.85*	40	9.11	40	9.12*
50	6.30	50	7.52	50	8.38*	50	8.93*	50	9.19	50	9.20*
60	6.39	60	7.60	60	8.47*	60	9.01*	60	9.28	60	9.28*
70	6.48	70	7.69	70	8.56*	70	9.10*	70	9.36	70	9.36*
90	6.57	80	7.78	80	8.64	80	9.19*	80	9.45	80	9.45*
90	6.66	90	7.87	90	8.73*	90	9.27*	90	9.53	90	9.53*
100	6.75	100	7.96	100	8.82*	100	9.36*	100	9.61	100	9.61*
150	7.17	150	8.37	150	9.23*	150	9.76*	150	10.01	150	10.01*
200	7.57	200	8.77	200	9.62*	200	10.15*	200	10.39	200	10.38*
250	7.96	250	9.16	250	10.00*	250	10.53*	250	10.77	250	10.75*
273	8.14	273	9.34	273	10.18	273	10.70	273	10.94	273	10.92
293	8.30	293	9.50	293	10.34*	293	10.86	293	11.09	293	11.07
300	8.36*	300	9.55	300	10.39*	300	10.91	300	11.14	300	11.12
350	8.75*	350	9.94	350	10.78	350	11.29	350	11.52	350	11.50
400	9.15*	400	10.33	400	11.17*	400	11.68*	400	11.90	400	11.87*
500	9.95*	500	11.13	500	11.95*	500	12.45*	500	12.67	500	12.62*
600	10.78*	600	11.95	600	12.76*	600	13.24*	600	13.44	600	13.39*
700	11.66*	700	12.81	700	13.60*	700	14.07*	700	14.26	700	14.19*
800	12.58*	800	13.71	800	14.49*	800	14.94*	800	15.11	800	15.02*
900	13.55*	900	14.67	900	15.42*	900	15.86*	900	16.01	900	15.90*
1000	14.58*	1000	15.68	1000	16.41*	1000	16.82*	1000	16.95	1000	16.82*
1100	15.68*	1100	16.78	1100	17.47*	1100	17.86*	1100	17.96	1100	17.81*
1200	16.86*	1200	17.90*	1200	18.59*	1200	18.96*	1200	19.04*	1200	18.86*

† Uncertainties in the electrical resistivity values are as follows:

85.00 Au - 15.00 Ag: ±1%.
80.00 Au - 20.00 Ag: ±1%.
75.00 Au - 25.00 Ag: ±1%.
70.00 Au - 30.00 Ag: ±1%.
65.00 Au - 35.00 Ag: ±1%.
60.00 Au - 40.00 Ag: ±1%.

* In temperature range where no experimental data are available.

TABLE 50. RECOMMENDED ELECTRICAL RESISTIVITY OF GOLD-SILVER ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Au: 55.00% (40.10 At.%) Ag: 45.00% (59.90 At.%)		Au: 50.00% (35.39 At.%) Ag: 50.00% (64.61 At.%)		Au: 45.00% (30.94 At.%) Ag: 55.00% (69.06 At.%)		Au: 40.00% (26.75 At.%) Ag: 60.00% (73.25 At.%)		Au: 35.00% (22.77 At.%) Ag: 65.00% (77.23 At.%)		Au: 30.00% (19.01 At.%) Ag: 70.00% (80.99 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	8.79*	1	8.37*	1	7.80*	1	7.13*	1	6.40*	1	5.61
4	8.79	4	8.37*	4	7.80	4	7.13	4	6.40*	4	5.61
7	8.79*	7	8.38*	7	7.80	7	7.14	7	6.40*	7	5.61
10	8.79*	10	8.38*	10	7.81	10	7.14	10	6.40*	10	5.61
15	8.80*	15	8.38*	15	7.81	15	7.14	15	6.41*	15	5.61
20	8.81*	20	8.39	20	7.82	20	7.15	20	6.41*	20	5.62
25	8.82*	25	8.40	25	7.83	25	7.16	25	6.43*	25	5.63
30	8.84*	30	8.42	30	7.85	30	7.18	30	6.44*	30	5.65
40	8.90*	40	8.48	40	7.91	40	7.24	40	6.50*	40	5.70
50	8.98*	50	8.55	50	7.98	50	7.30	50	6.56*	50	5.77
60	9.06*	60	8.63	60	8.06	60	7.38	60	6.64*	60	5.84
70	9.14*	70	8.72	70	8.14	70	7.46	70	6.72*	70	5.92
80	9.22	80	8.80	80	8.22	80	7.54	80	6.80*	80	5.99
90	9.31*	90	8.88	90	8.30	90	7.62	90	6.87*	90	6.07
100	9.39*	100	8.96	100	8.37	100	7.69	100	6.95*	100	6.15
150	9.77*	150	9.34	150	8.75	150	8.06	150	7.31*	150	6.50
200	10.14*	200	9.70	200	9.11	200	8.42	200	7.66*	200	6.85
250	10.51*	250	10.06	250	9.46	250	8.76	250	8.00*	250	7.18
273	10.68	273	10.23	273	9.62	273	8.92	273	8.16*	273	7.34
293	10.82	293	10.37	293	9.76	293	9.06	293	8.29	293	7.47
300	10.87	300	10.42	300	9.81	300	9.11	300	8.34	300	7.52
350	11.23	350	10.78	350	10.16	350	9.46*	350	8.68*	350	7.85
400	11.60*	400	11.14*	400	10.52	400	9.81*	400	9.03*	400	8.19*
500	12.34*	500	11.87*	500	11.24	500	10.52*	500	9.73*	500	8.88*
600	13.10*	600	12.62*	600	11.98	600	11.24*	600	10.44*	600	9.58*
700	13.89*	700	13.39*	700	12.74	700	11.99*	700	11.18*	700	10.30*
800	14.71*	800	14.20*	800	13.53	800	12.77*	800	11.94*	800	11.05*
900	15.57*	900	15.03*	900	14.35	900	13.57*	900	12.73*	900	11.82*
1000	16.47*	1000	15.91*	1000	15.21	1000	14.41*	1000	13.55*	1000	12.63*
1100	17.44*	1100	16.86*	1100	16.13	1100	15.31*	1100	14.42*	1100	13.48*
1200	18.47*	1200	17.86*	1200	17.10	1200	16.25*	1200	15.34*	1200	14.38*

† Uncertainties in the electrical resistivity values are as follows:

55.00 Au - 45.00 Ag: ±1%.
50.00 Au - 50.00 Ag: ±1%.
45.00 Au - 55.00 Ag: ±1%.
40.00 Au - 60.00 Ag: ±1%.
35.00 Au - 65.00 Ag: ±1%.
30.00 Au - 70.00 Ag: ±2% up to 400 K and ±1% above 400 K.

* In temperature range where no experimental data are available.

TABLE 50. RECOMMENDED ELECTRICAL RESISTIVITY OF GOLD-SILVER ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Au: 25.00% (15.44 At.%) Ag: 75.00% (84.56 At.%)		Au: 20.00% (12.04 At.%) Ag: 80.00% (87.96 At.%)		Au: 15.00% (8.81 At.%) Ag: 85.00% (91.19 At.%)		Au: 10.00% (5.74 At.%) Ag: 90.00% (94.26 At.%)		Au: 5.00% (2.80 At.%) Ag: 95.00% (97.20 At.%)		Au: 3.00% (1.67 At.%) Ag: 97.00% (98.33 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	4.75*	1	3.85*	1	2.90*	1	1.94*	1	0.964*	1	0.577*
4	4.75*	4	3.85	4	2.90	4	1.94	4	0.964	4	0.577
7	4.76*	7	3.85*	7	2.91	7	1.94*	7	0.965*	7	0.578
10	4.76*	10	3.85*	10	2.91	10	1.94*	10	0.966*	10	0.579
15	4.76*	15	3.86*	15	2.91	15	1.94*	15	0.970*	15	0.583
20	4.77*	20	3.86*	20	2.92	20	1.95*	20	0.976*	20	0.588
25	4.78*	25	3.87*	25	2.93	25	1.96*	25	0.985*	25	0.599
30	4.80*	30	3.89*	30	2.94	30	1.98*	30	1.00*	30	0.614
40	4.85*	40	3.94*	40	2.99	40	2.02*	40	1.05*	40	0.659
50	4.91*	50	4.00*	50	3.05	50	2.08*	50	1.11*	50	0.716
60	4.99*	60	4.07*	60	3.12	60	2.15*	60	1.17*	60	0.779
70	5.06*	70	4.15*	70	3.19	70	2.22*	70	1.24*	70	0.845
80	5.14	80	4.22*	80	3.27	80	2.29*	80	1.31*	80	0.911
90	5.21*	90	4.30*	90	3.34	90	2.37*	90	1.38*	90	0.977
100	5.29*	100	4.37*	100	3.42	100	2.44*	100	1.44	100	1.04
150	5.64*	150	4.72*	150	3.76	150	2.77*	150	1.76	150	1.35
200	5.98*	200	5.05*	200	4.08	200	3.09*	200	2.08	200	1.66
250	6.31*	250	5.37*	250	4.40	250	3.40*	250	2.38	250	1.96
273	6.46	273	5.52	273	4.55	273	3.54	273	2.52	273	2.06
293	6.59	293	5.65*	293	4.67	293	3.66	293	2.64*	293	2.20
300	6.63	300	5.70*	300	4.72	300	3.71	300	2.68*	300	2.24*
350	6.96	350	6.02*	350	5.03	350	4.00	350	2.96*	350	2.52*
400	7.30*	400	6.34*	400	5.34	400	4.31	400	3.25*	400	2.82*
500	7.97*	500	7.00*	500	5.99	500	4.93	500	3.86*	500	3.43*
600	8.66*	600	7.68*	600	6.65	600	5.57	600	4.49*	600	4.07*
700	9.37*	700	8.37*	700	7.32	700	6.24	700	5.15*	700	4.73*
800	10.10*	800	9.09*	800	8.02	800	6.93	800	5.83*	800	5.41*
900	10.85*	900	9.83*	900	8.74	900	7.64	900	6.54*	900	6.11*
1000	11.64*	1000	10.59*	1000	9.50	1000	8.39	1000	7.27*	1000	6.84*
1100	12.47*	1100	11.41*	1100	10.31	1100	9.19	1100	8.06*	1100	7.64*
1200	13.36*	1200	12.28*	1200	11.17*	1200	10.04*	1200	8.90*	1200	8.55*

† Uncertainties in the electrical resistivity values are as follows:

25.00 Au - 75.00 Ag: ±2% up to 400 K and ±1% above 400 K.
20.00 Au - 80.00 Ag: ±2%.
15.00 Au - 85.00 Ag: ±2%.
10.00 Au - 90.00 Ag: ±3% up to 200 K and ±2% above 200 K.
5.00 Au - 95.00 Ag: ±4%.
3.00 Au - 97.00 Ag: ±4% up to 200 K and ±3% above 200 K.

* In temperature range where no experimental data are available.

TABLE 50. RECOMMENDED ELECTRICAL RESISTIVITY OF GOLD-SILVER ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Au: 1.00% (0.55 At.%) Ag: 99.00% (99.45 At.%)		Au: 0.50% (0.27 At.%) Ag: 99.50% (99.73 At.%)		Au: 0.00% (0.00 At.%) Ag: 100.00% (100.00 At.%)	
T	ρ	T	ρ	T	ρ
1	0.193*	1	0.097	1	0.00100
4	0.193	4	0.097	4	0.00100
7	0.194	7	0.098	7	0.00103
10	0.196	10	0.099	10	0.00115
15	0.199	15	0.102	15	0.00190
20	0.205	20	0.107	20	0.00423
25	0.216	25	0.115	25	0.00959
30	0.230	30	0.126	30	0.0195
40	0.269	40	0.162	40	0.0541
50	0.319	50	0.210	50	0.104
60	0.377	60	0.269	60	0.163
70	0.440	70	0.332	70	0.226
80	0.503	80	0.395	80	0.290
90	0.566	90	0.458	90	0.355
100	0.627	100	0.521	100	0.419
150	0.935	150	0.834	150	0.728
200	1.25	200	1.15	200	1.031
250	1.56	250	1.45	250	1.330
273	1.69	273	1.58	273	1.468
293	1.80	293	1.69	293	1.587
300	1.84*	300	1.73*	300	1.629
350	2.12*	350	2.02*	350	1.930
400	2.42*	400	2.33*	400	2.236
500	3.04*	500	2.95*	500	2.863
600	3.69*	600	3.60*	600	3.509
700	4.35*	700	4.26*	700	4.174
800	5.03*	800	4.94*	800	4.860
900	5.73*	900	5.65*	900	5.565
1000	6.47*	1000	6.40*	1000	6.297
1100	7.28*	1100	7.19*	1100	7.085
1200	8.13*	1200	8.03*	1200	7.922
				1235.08	8.233(s)
				1236	17.31(ℓ)
				1400	18.69
				1600	20.38

† Uncertainties in the electrical resistivity values are as follows:

1.00 Au - 99.00 Ag: ±4% up to 100 K and ±3% above 100 K.
0.50 Au - 99.50 Ag: ±4% up to 100 K and ±3% above 100 K.
0.00 Au - 100.00 Ag: ±1% up to 10 K, ±5% above 10 K to 30 K, ±2% above 30 K to 70 K, ±1% above 70 K to 400 K, ±2% above 400 K to 1235.08 K, and ±4% above 1235.08 K.

* In temperature range where no experimental data are available.

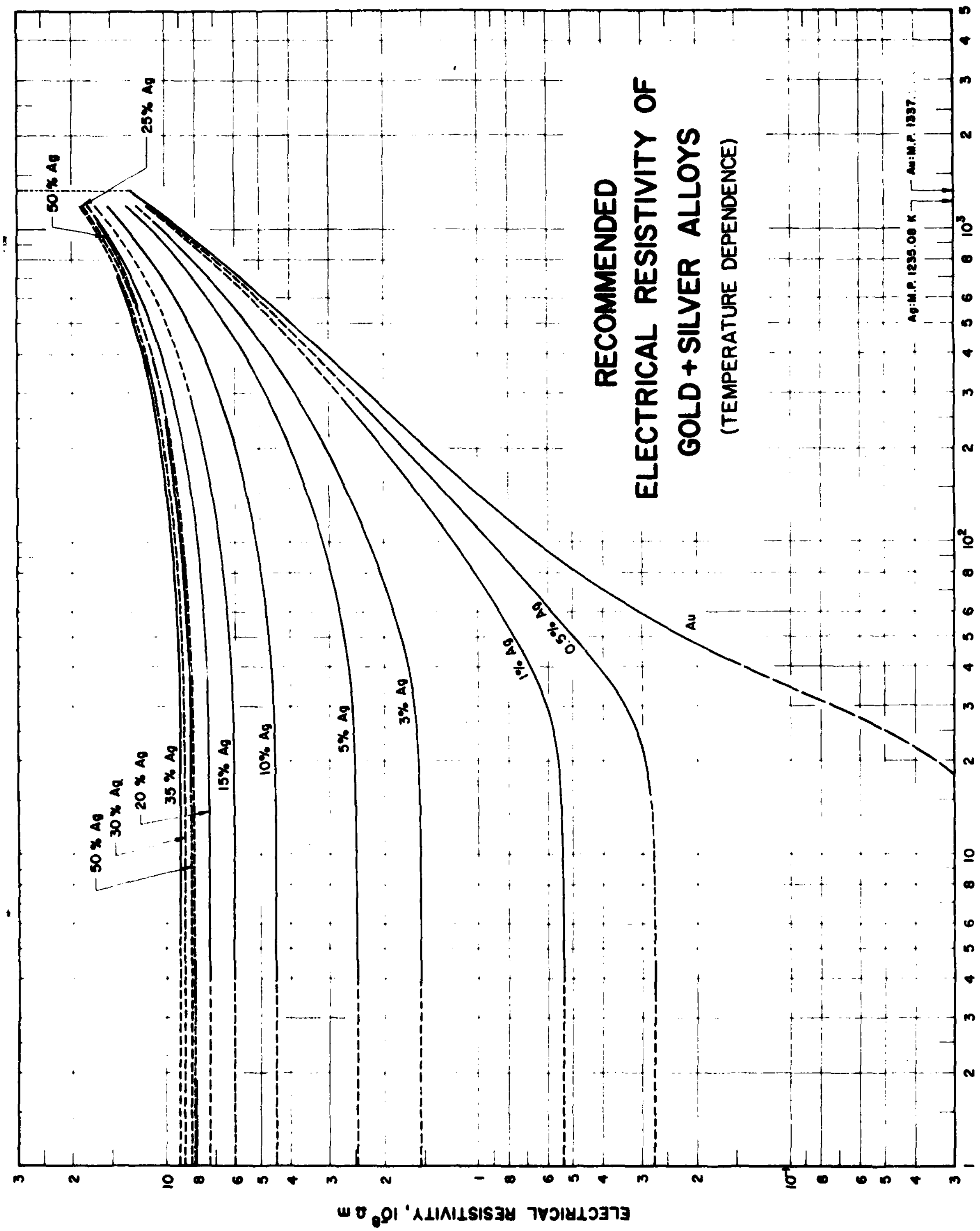

RECOMMENDED
ELECTRICAL RESISTIVITY OF
GOLD + SILVER ALLOYS
(TEMPERATURE DEPENDENCE)
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE, K
Au
0.5% Ag
1% Ag
3% Ag
5% Ag
10% Ag
15% Ag
20 % Ag
25% Ag
30 % Ag
35 % Ag
50 % Ag
Ag: M.P. 1235.08 K
Au: M.P. 1337
CINDAS

FIGURE 38

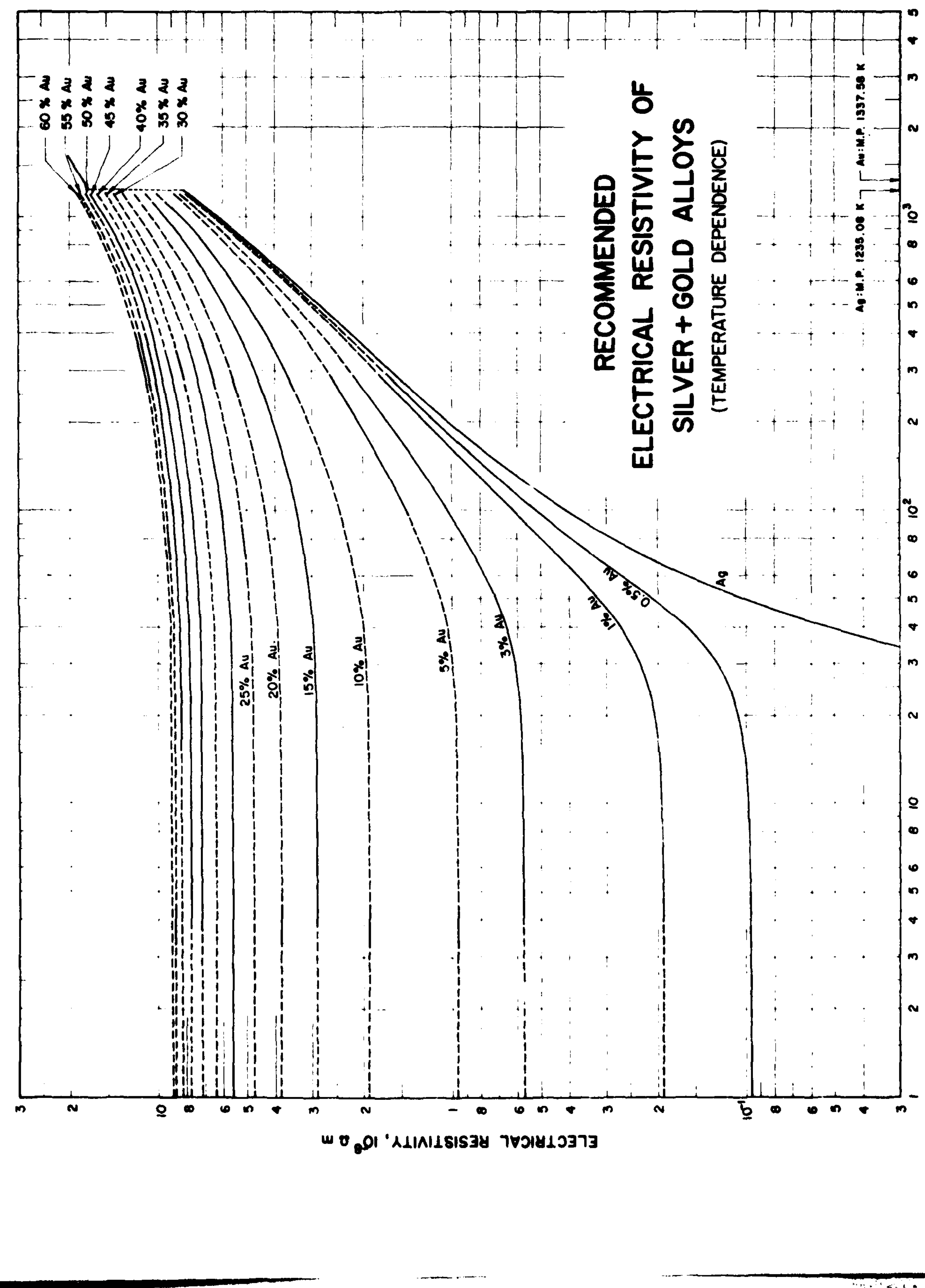
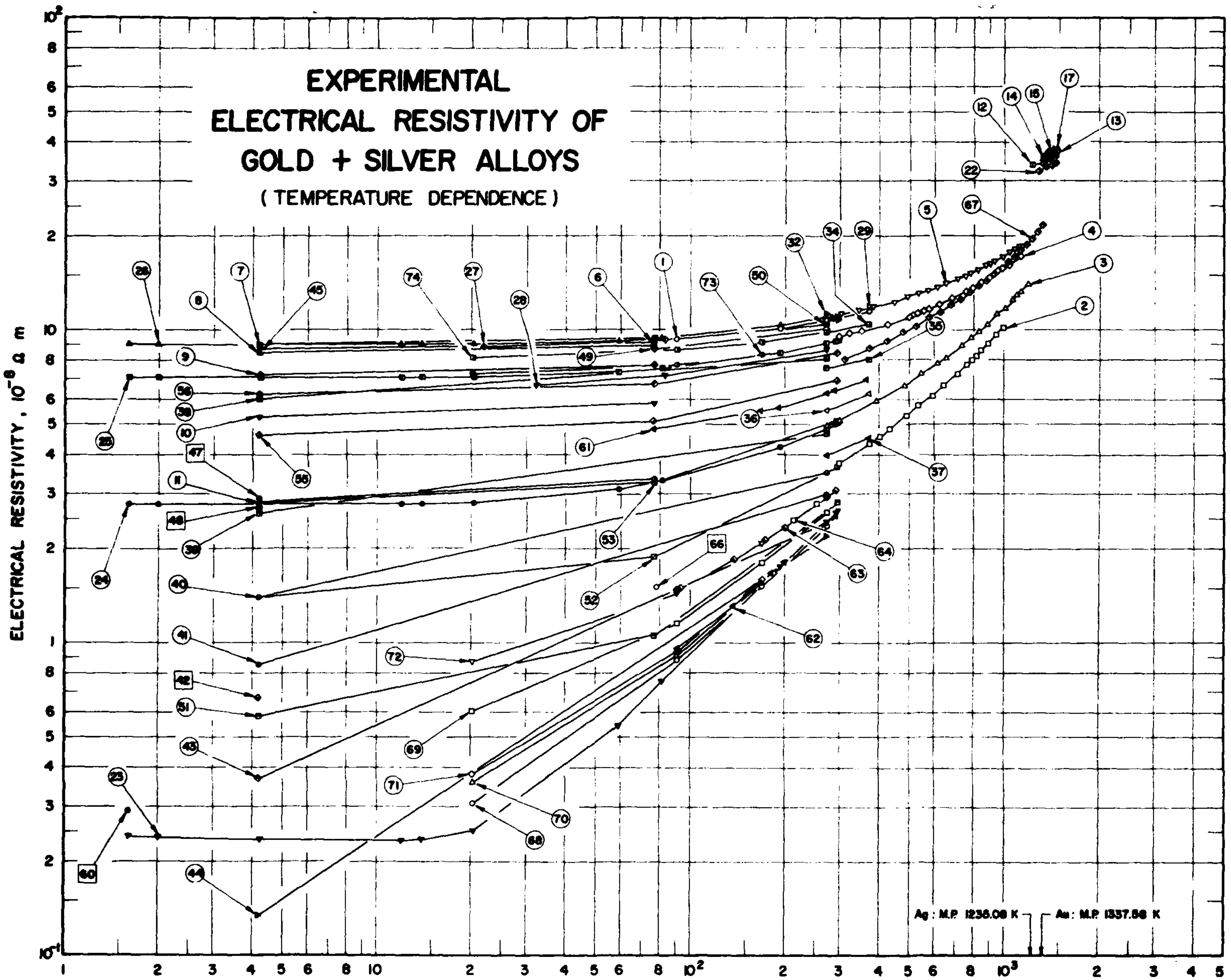

RECOMMENDED
ELECTRICAL RESISTIVITY OF
SILVER + GOLD ALLOYS
(TEMPERATURE DEPENDENCE)
60 % Au
55 % Au
50 % Au
45 % Au
40% Au
35 % Au
30 % Au
25% Au
20% Au
15% Au
10% Au
5% Au
3% Au
1% Au
0.5% Au
Ag
Ag: M.P. 1235.08 K
Au: M.P. 1337.58 K
TEMPERATURE, K
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
CINDAS

FIGURE 39



CINDAS

FIGURE 40

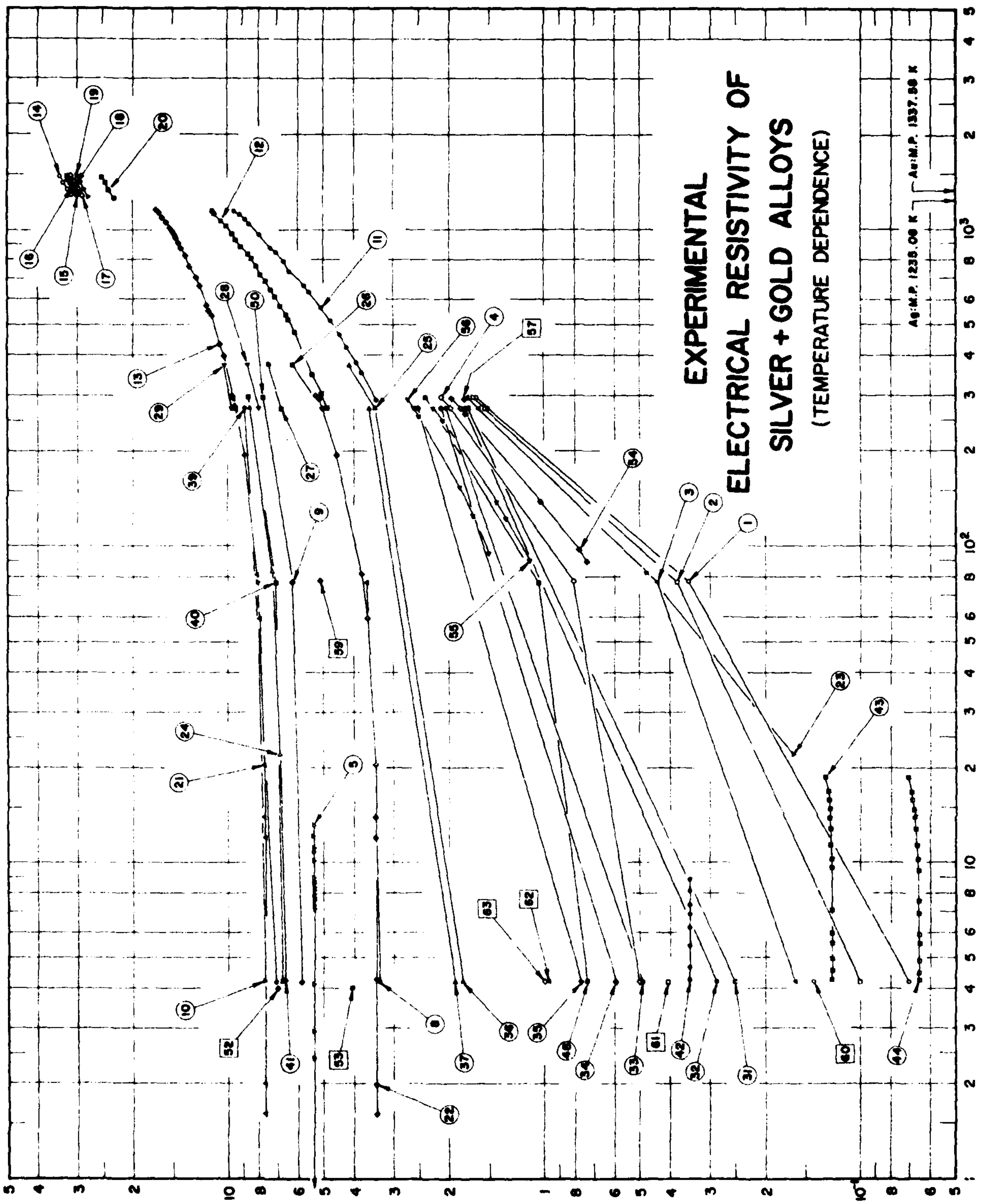

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
SILVER + GOLD ALLOYS
(TEMPERATURE DEPENDENCE)
Ag:M.P. 1235.08 K
Au:M.P. 1337.58 K
TEMPERATURE, K
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
CINDAS

FIGURE 41

TABLE 51. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + SILVER ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Ag	Composition (continued), Specifications, and Remarks
1	258	Broom, T.	1952	B	90-373		66.13		Wire specimen 1.83 mm (0.072 in) in diam; annealed at 873 K for 2 h and furnace cooled; uncertainty in diam ± 0.0001 in; tabular data presentation; resistivity change after 37% deformation by drawing was 0.375 x 10^{-8} Ωm at 90 K.
2	302	Iyer, V.K. and Asimow, R.M.	1967		299-998			2.8	Calculated composition (5 a/o Ag), less than 0.1 total impurity with 0.05 Si indicated by spectrographic analysis; 99.999 Ag and Au melted in graphite crucible in Ar, evaporation of Ag resulted in composition change of less than 0.2 a/o; 3.18 mm (0.125 in) diam ingots swaged to 1.02 mm (0.040 in) and drawn to 0.254 mm (0.010 in); annealed in Ar; maintained in Ar above 673 K to prevent evaporation of Ag but measured in vacuum, different specimen measured in 273-303 K range than at higher temperatures, identical values obtained for at least two heating cycles; uncertainty in temperature ± 0.3% T (in °C), standard deviation of points from best fitted curve less than 0.5% of the mean, resistivity accurate to within 2% with error mainly due to length and density uncertainty; data corrected for thermal expansion; data read from figure.
3	302	Iyer, V.K. and Asimow, R.M.	1967		274-1194			5.74	Calculated composition (10 a/o Ag); similar to the above specimen.
4	302	Iyer, V.K. and Asimow, R.M.	1967		298-1134			19.0	Calculated composition (30 a/o Ag); similar to the above specimen.
5	302	Iyer, V.K. and Asimow, R.M.	1967		276-1123			35.4	Calculated composition (50 a/o Ag); similar to the above specimen.
6	300	Boes, J., Van Dam, A.J., and Bijovet, J.	1968		4.2, 77		54.9		Calculated composition (40 a/o Au); strip specimen 1 x 1 x 30 mm made by arc melting in Ar and rolling the ingot; data extracted from table.
7	300	Boes, J., et al.	1968		4.2, 77		64.6		Calculated composition (50 a/o Au); similar to the above specimen.
8	300	Boes, J., et al.	1968		4.2, 77		73.3		Calculated composition (60 a/o Au); similar to the above specimen.
9	300	Boes, J., et al.	1968		4.2, 77		81.0		Calculated composition (70 a/o Au); similar to the above specimen.
10	300	Boes, J., et al.	1968		4.2, 77		88.0		Calculated composition (80 a/o Au); similar to the above specimen.
11	300	Boes, J., et al.	1968		4.2, 77		94.3		Calculated composition (90 a/o Au); similar to the above specimen.
12	127	Roll, A. and Motz, H.	1957	E	1332-1462		92.7		Calculated composition (87.5 a/o Au); measured in liquid state; prepared from 99.995 pure Ag and 99.95 pure Au; $d\rho/dT$ = 0.0159 x 10^{-8} Ωm K^{-1}; ± 1% uncertainty in resistivity; data read from figure.
13	127	Roll, A. and Motz, H.	1957	E	1324-1462		84.6		Calculated composition (75 a/o Au); similar to the above specimen but with $d\rho/dT$ = 0.0168 x 10^{-8} Ωm K^{-1}.
14	127	Roll, A. and Motz, H.	1957	E	1322-1462		82.4		Calculated composition (72 a/o Au); similar to the above specimen but with $d\rho/dT$ = 0.0155 x 10^{-8} Ωm K^{-1}.
15	127	Roll, A. and Motz, H.	1957	E	1320-1461		81.0		Calculated composition (70 a/o Au); similar to the above specimen but with $d\rho/dT$ = 0.0169 x 10^{-8} Ωm K^{-1}.
16*	127	Roll, A. and Motz, H.	1957	E	1318-1460		79.5		Calculated composition (68 a/o Au); similar to the above specimen but with $d\rho/dT$ = 0.0191 x 10^{-8} Ωm K^{-1}.

* Not shown in figure.

TABLE 51. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + SILVER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Ag	Composition (continued), Specifications, and Remarks
17	127	Roll, A. and Motz, H.	1957	E	1317-1459		78.53		Calculated composition (66.7 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0175 \times 10^{-8}\ \Omega m\ K^{-1}$.
18*	127	Roll, A. and Motz, H.	1957	E	1317-1459		78.0		Calculated composition (66 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0172 \times 10^{-8}\ \Omega m\ K^{-1}$.
19*	127	Roll, A. and Motz, H.	1957	E	1316-1458		77.2		Calculated composition (65 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0145 \times 10^{-8}\ \Omega m\ K^{-1}$.
20*	127	Roll, A. and Motz, H.	1957	E	1313-1460		73.3		Calculated composition (60 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0148 \times 10^{-8}\ \Omega m\ K^{-1}$.
21*	127	Roll, A. and Motz, H.	1957	E	1304-1460		64.6		Calculated composition (50 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0138 \times 10^{-8}\ \Omega m\ K^{-1}$.
22	127	Roll, A. and Motz, H.	1957	E	1290-1461		52.28		Calculated composition (37.5 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0116 \times 10^{-8}\ \Omega m\ K^{-1}$.
23	297	Giauque, W.F. and Stout, J.W.	1938	A	1.6-298	No. 6		0.1	Readily available thermometer-heater wire containing about 0.1% Ag investigated without removal from the spool on which it was supplied; wire had been annealed and then insulated with a double layer of silk but was not re-annealed after winding on spool, however prior to the measurement of the following values the specimen was accidentally heated for 6 to 8 h at 373 K: 0.2408 and $0.2356 \times 10^{-8}\ \Omega m$ at 1.63 and 4.23 K, respectively; measurement techniques, uncertainties, and treatment of data the same as for curve 24.
24	297	Giauque, W.F. and Stout, J.W.	1938	A	1.6-298	No. 5		5.73	Drawn wire 0.579 mm in diam and about 100 cm long; annealed by heating to redness in a flame during and after drawing, wound loosely on a spool in insulated layers, and again annealed at 383 K for about 15 h; measured in four cooling cycles over period of 2.5 years; resistance ratio as a function of temperature and specific resistance at 273 K reported, from which resistivity was calculated by CINDAS, without correcting for thermal expansion; resistance accurate to 0.01%, resistivity to 1%; data extracted from table.
25	297	Giauque, W.F. and Stout, J.W.	1938	A	1.6-298	No. 4		18.99	Similar to the above specimen.
26	297	Giauque, W.F. and Stout, J.W.	1938	A	1.6-298	No. 3		35.33	Similar to the above specimen.
27	128	Grüneisen, E. and Reddemann, H.	1934		22-273	6		35.4	Calculated composition (50 a/o Ag); single crystal specimen; data extracted from table.
28	128	Grüneisen, E. and Reddemann, H.	1934		32-273	7		15.5	Calculated composition (25 a/o Ag); single crystal; data extracted from table.
29	130	Sedstrom, E.	1919		273, 373		54.62		Calculated composition (39.7 a/o Au); specimen rolled and drawn to thickness of 1 mm and heated 0.5 h at temperature near the melting point; data extracted from table.
30*	130	Sedstrom, E.	1919		273, 373		60.32		Calculated composition (45.4 a/o Au); similar to the above specimen.
31*	130	Sedstrom, E.	1919		273, 373		65.46		Calculated composition (50.9 a/o Au); similar to the above specimen.

* Not shown in figure.

TABLE 51. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + SILVER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Ag	Composition (continued), Specifications, and Remarks
32	130	Sedstrom, E.	1919		273, 373		69.17		Calculated composition (55.1 a/o Au); similar to the above specimen.
33*	130	Sedstrom, E.	1919		273, 373		73.19		Calculated composition (59.9 a/o Au); similar to the above specimen.
34	130	Sedstrom, E.	1919		273, 373		81.23		Calculated composition (70.3 a/o Au); similar to the above specimen.
35	130	Sedstrom, E.	1919		273, 373		88.82		Calculated composition (81.3 a/o Au); similar to the above specimen.
36	130	Sedstrom, E.	1919		273, 373		93.84		Calculated composition (89.3 a/o Au); similar to the above specimen.
37	130	Sedstrom, E.	1919		273, 373		97.26		Calculated composition (95.1 a/o Au); similar to the above specimen.
38	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			12.7	Composition (21.0 a/o Ag) estimated by author using Nordheim's rule and the values of residual resistivity per atomic percent solute reported by J.O. Linde (Thesis, University of Stockholm, 1939); 1 mm diam wire specimens prepared from 99.9999 Ag and 99.999 or 99.9999 Au were supplied in three batches by Cambridge Metals Research Ltd; similar specimens analyzed for Fe content by D.S. Russell, Division of Applied Chemistry, N.R.C. of Canada contained 1.7 to 9.0 atomic p.p.m. of Fe; specimen as received was drawn down, etched, washed in distilled water and alcohol, dried, sealed in quartz capsule with 0.33 atm oxygen to minimize Fe contamination, and annealed at 1173 K for 72 h; uncertainty in temperature less than 0.05 K at all temperatures, 1% error in absolute resistivity; measurement temperature of the residual resistivity not stated explicitly, assumed to be 4.2 K; data extracted from table.
39	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			4.43	Estimated composition (7.8 a/o Ag); similar to the above specimen.
40	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			2.29	Estimated composition (4.1 a/o Ag); similar to the above specimen.
41	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			1.33	Estimated composition (2.4 a/o Ag); similar to the above specimen.
42	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			1.05	Estimated composition (1.9 a/o Ag); similar to the above specimen.
43	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			0.47	Estimated composition (0.85 a/o Ag); similar to the above specimen.
44	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			0.203	Estimated composition (0.37 a/o Ag); similar to the above specimen.
45	135	Huray, P.G., Roberts, L.D., and Thomson, J.O.	1971		4.2-296	AgAu		35.39	Calculated composition (50 a/o Ag), chemical analysis by Johnson Matthey Chemicals Ltd. of similar specimens indicated composition uncertainty of 0.5 a/o; foil specimen 0.0508 mm (2 mil) thick and uniform to at least 1%; 99.99 Ag and Au arc-melted and cooled in Ar several times and drop cast (poured) into water-cooled cylindrical mold, cylinders annealed in inert atmosphere for 5 d within 50 K of mp, strips cut lengthwise from cylinder and rolled to final thickness with intermittent annealing; finally annealed for 100 h at 641 K, furnace cooled to 523 K, maintained at 523 K for 120 h, and quenched into water at room temperature; uncertainty in thickness less than 1%, uncertainties in resistivity ±0.09, ±0.09, and ±0.11 x 10^{-8} Ωm at 4.2, 77, and 296 K, respectively; data extracted from table.

* Not shown in figure.

TABLE 51. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + SILVER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Ag	Composition (continued), Specifications, and Remarks
46*	135	Huray, P.G., Roberts, L.D., and Thomson, J.O.	1971		4.2-296	AgAu		35.39	Similar to the above specimen except finally suspended in vacuum furnace at 873 K for 30 min or more, then dropped in vacuum into bath of vacuum-pump oil at room temperature.
47	77	Kapoor, A., Rowlands, J.A., and Woods, S.B.	1974		4.2			5.74	Calculated composition (10 a/o Ag); polycrystalline square rod 4 mm^2 in cross section and 10 cm long; 99.999 pure metals induction melted in recrystallized alumina crucibles in Ar and resulting ingot rolled to size; cold worked; resistivity found to be independent of temperature between 1 and 4 K; uncertainty in resistivity $\pm 2\%$; data extracted from table.
48	77	Kapoor, A., et al.	1974		4.2			5.74	The above specimen annealed in vacuum for 12 h at 1000 K.
49	303	Van der Sijde, B.	1963		77,273		74.9		Calculated composition (62 a/o Au); wire specimen of 0.3 mm diam; heated at 1148 K for 10 min in air and cooled slowly; data extracted from table.
50	303	Van der Sijde, B.	1963		77,273		64.6		Calculated composition (50 a/o Au); wire specimen of 0.25 mm diam; heated at 873 K for 2 h in vacuum and cooled slowly; data extracted from table.
51	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2-295			1.1	Calculated composition (2.0 a/o Ag): parallelopiped specimen 0.100 x 0.100 x 1.25 in; 99.999$^+$ pure Ag and Au induction melted in helium, cast in ingots, cold worked, etched in 10% KCN, homogenized at 1073 K for 72 h, and quenched in cold water; specimen machined from axial section of ingot, etched in KCN, again heated at 1073 K for 72 h, and quenched; KCN etching and use of tungsten carbide tools reduced ferromagnetic impurities; uncertainty in resistivity 1.5%; measurements at ambient temperature were reported as being at 295 ± 3 K; data extracted from table.
52	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2-295			2.8	Calculated composition (5.0 a/o Ag); similar to the above specimen.
53	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2-295	a, Sample No. 1		5.7	Calculated composition (10.0 a/o Ag); similar to the above specimen.
54*	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2-295	b, Sample No. 2		5.7	Calculated composition (10.0 a/o Ag); similar to the above specimen.
55	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2-295			10.4	Calculated composition (17.5 a/o Ag); similar to the above specimen.
56	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2-295			15.4	Calculated composition (25.0 a/o Ag); similar to the above specimen.
57*	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2-295			35.4	Calculated composition (50.0 a/o Ag); similar to the above specimen.
58*	301	Stewart, R.G. and Huebener, R.P.	1970	A	1.6		99.86	0.14	Calculated composition (0.25 a/o Ag); impurities less than 2 ppm; concentrations determined by wet chemical and neutron activation analyses; polycrystalline wire 10 mil in diameter; obtained from Cominco American, Inc. or Sigmund Cohn, Inc.; rinsed in dilute nitric acid for 20 min, distilled water, and pure alcohol prior to spotwelding to mount; annealed by Joule heating in air starting at 1223 K and ending with 24 h period at 1023 K; cooled to room temperature within 1 h; measured under less than 10^{-4} Torr; temperature measurements accurate to within 0.25 K; geometrical factor accurate to $\pm 0.5\%$; deviations from Matthiessen's rule reported from 1.6-373 K; data reported as residual resistivity; lowest measurement temperature 1.6 K; data extracted from table.

* Not shown in figure.

TABLE 51. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + SILVER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Ag	Composition (continued), Specifications, and Remarks
59*	301	Stewart, R.G. and Huebener, R.P.	1970	A	1.6		99.95	0.05	Calculated composition (0.09 a/o Ag); similar to the above specimen.
60	301	Stewart, R.G. and Huebener, R.P.	1970	A	1.6		99.48	0.52	Calculated composition (0.945 a/o Ag); similar to the above specimen.
61	304	Dewar, J. and Fleming, J.A.	1893	B	76-365		90	10	Wire specimen of the order of 0.08-0.25 mm in diam and 1-3 m in length; wound on vulcanized fiber cylinder, annealed in melted paraffin wax at 473 K, and cooled slowly; measured in boiling oxygen under 760 mm Hg, liquid ethylene, carbon dioxide and ether, melting ice, air, and boiling water; temperatures measured using the resistance of a pure, soft, carefully annealed platinum wire as thermometric property without correcting to absolute thermodynamic scale; no correction for thermal expansion; units of composition not stated, assumed to be weight percent; data extracted from table.
62	37	Linde, J.O.	1931		91-291			0.545	Calculated composition (0.99 a/o Ag); Au from Heraeus and Ag from Kahlbaum melted together under vacuum of about 0.1 mm Hg, homogenized 10-20 h at temperatures near the melting point, formed into square rods of 1.2 mm thickness, drawn through steel or sapphire dies to round wires of 0.75 mm diam and 1.2 cm length, and finally annealed at 773 K; diam measured with micrometer to ± 0.003 mm; data extracted from table.
63	37	Linde, J.O.	1931		91-291			1.59	Calculated composition (2.87 a/o Ag); similar to the above specimen.
64	37	Linde, J.O.	1931		214-242			1.63	Calculated composition (2.93 a/o Ag); similar to the above specimen but annealed at 1073 K.
65*	37	Linde, J.O.	1931		291			1.04	Calculated composition (1.88 a/o Ag); similar to the above specimen but annealing temperature unknown.
66	305	Dawson, H.I.	1965	A	78		98.00	2.00	Calculated composition (3.6 a/o Ag); impurity concentration a few times 10^{-4}; 0.20 or 0.25 mm diam wire; approximate grain size 0.04 mm; annealed at 723 K for 1 h under vacuum of 10^{-5} mm Hg; measured in stirred liquid nitrogen; smallest detectable change in resistivity less than 10^{-13} Ωm; data extracted from table.
67	295	Giardina, M.D., Schüle, W., Frank, W., and Seeger, A.	1972		310-1323			9.61	Calculated composition (16.25 a/o Ag); 0.4 mm diam wire specimen; measured during heating (at a rate of about 0.5 K min^{-1}) after slow cooling; data extracted from smooth curve without data points.
68	306	Clay, J.	1908		20-273	No. I	99.604		Although resistivities were reported as being for 0.396% Ag alloy, analysis after measurement actually showed only 0.14% Ag with 0.05% Fe and the rest of the admixture due to other impurities; alloy supplied by Dr. Hoitsema, drawn by Heraeus to wires of 0.1 mm diam, annealed, and wound around glass cylinders; resistances measured and reported from 12-170 K; resistivities deduced from resistance measurements and the resistivity at 273 K, calculated according to Matthiessen's observations; data extracted from table.
69	306	Clay, J.	1908		20-273	No. IV	99.132		Similar to the above specimen; resistivities reported as being for 0.868% Ag but analysis showed 0.65% Ag, 0.09% Fe, and the balance other impurities.

* Not shown in figure.

TABLE 51. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD + SILVER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Au	Ag	Composition (continued), Specifications, and Remarks
70	306	Clay, J.	1908		20-273	No. II	99.524		Similar to the above specimen; total admixture 0.476%.
71	306	Clay, J.	1908		20-273	No. III	99.476		Similar to the above specimen; total admixture 0.524%.
72	306	Clay, J.	1908		20-273	No. V	98.598		Similar to the above specimen; total admixture 1.402%.
73	306	Clay, J.	1908		20-273	No. VI		20.037	Similar to the above specimen, but analysis before drawing showed 20.050% Ag and analysis after measurement showed 20.037% Ag; also this specimen was cleaned with acids each time it was drawn so that impurity content should be less.
74	306	Clay, J.	1908		20-273	No. VII		47.985	Similar to the above specimen; analysis before drawing showed 48.020% Ag, after measurement 47.985% Ag.

TABLE 52. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD + SILVER ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

T	ρ
DATA SET 1	
90.2	9.38
194.7	10.10
273.2	10.78
373.2	11.55
DATA SET 2	
299	3.76
376	4.35
404	4.59
437	4.85
492	5.35
538	5.73
593	6.18
643	6.65
714	7.26
766	7.76
792	8.01
818	8.30
859	8.64
896	9.06
946	9.63
998	10.21
DATA SET 3	
274	4.97
300	5.17
394	5.96
484	6.67
557	7.29
615	7.84
652	8.15
738	8.95
787	9.44
839	9.94
888	10.46
957	11.29
1009	11.87
1069	12.53
1098	12.95
1139	13.37
1194	14.07
DATA SET 4	
298	9.53
322	9.76
353	9.94
428	10.46
500	11.07
513	11.22
531	11.35
554	11.51
577	11.72
622	12.12
687	12.70
758	13.36
793	13.70
842	14.27
899	14.75
955	15.53
983	15.77
1040	16.20
1134	17.28
DATA SET 5	
276	11.04
301	11.27
346	11.61
384	11.92
450	12.34
495	12.81
535	13.09
576	13.40
615	13.74
657	14.08
714	14.60
755	14.86
786	15.22
830	15.63
879	16.08
904	16.37
938	16.70
991	17.23
1049	17.80
1088	18.19
1123	18.57
DATA SET 6	
4.2	8.82*
77	9.17
DATA SET 7	
4.2	8.98
77	9.41
DATA SET 8	
4.2	8.47
77	8.95
DATA SET 9	
4.2	7.20
77	7.72
DATA SET 10	
4.2	5.29
77	5.81
DATA SET 11	
4.2	2.83
77	3.36
DATA SET 12	
1232	33.9
1342	34.1
1362	34.6*
1382	34.9*
1402	35.2
1422	35.5*
1441	35.9*
1462	36.2
DATA SET 13	
1324	34.6*
1343	35.0
1362	35.5*
1382	35.8*
1401	36.2
DATA SET 13 (cont.)	
1422	36.5*
1441	36.8*
1462	37.2
DATA SET 14	
1322	35.5*
1343	35.8
1362	36.2*
1382	36.5*
1402	36.8*
1421	37.1*
1442	37.5*
1462	37.8*
DATA SET 15	
1320	34.9*
1342	35.3*
1362	35.8
1382	36.0*
1402	36.4*
1421	36.9
1442	37.1*
1461	37.5*
DATA SET 16*	
1318	35.1
1341	35.7
1360	36.0
1381	36.4
1400	36.8
1419	37.3
1440	37.7
1460	38.0
DATA SET 17	
1317	35.7*
1340	36.3*
1361	36.6*
1379	37.0
1400	37.4*
1418	37.6*
1439	38.2
1459	38.4
DATA SET 18*	
1317	35.4
1320	35.7
1340	36.0
1360	36.3
1379	36.7
1400	36.9
1418	37.3
1439	37.6
1459	38.0
DATA SET 19*	
1316	35.2
1320	35.2
1340	35.7
1360	35.9
1378	36.2
1399	36.4
1418	36.8
1438	37.2
1458	37.5
DATA SET 20*	
1313	34.7
1321	34.8
1341	35.3
1361	35.7
1381	35.9
1401	36.2
1420	36.5
1440	36.9
1460	37.3
DATA SET 21*	
1304	34.6
1322	34.9
1342	35.3
1360	35.4
1380	35.8
1400	36.1
1419	36.4
1440	36.8
1460	37.0
DATA SET 22	
1290	32.3
1322	32.4*
1341	32.7*
1360	33.1
1381	33.2*
1402	33.5*
1419	33.7
1440	34.1*
1461	34.2
DATA SET 23	
1.6	0.2416
1.63	0.2405*
1.98	0.2405
4.23	0.2364
4.24	0.2364*
4.23	0.2363*
4.23	0.2356*
4.23	0.0236*
12.0	0.2349
12.0	0.2349*
13.92	0.2368
13.92	0.2368*
20.44	0.2527
20.44	0.2527*
20.45	0.2527*
59.17	0.5462
81.36	0.7537
81.37	0.7539*
194.62	1.7560
273.10	2.44
293.57	2.62
296.2	2.64
298.36	2.66
DATA SET 24	
1.6	2.788
1.63	2.785*
1.98	2.787
4.23	2.787*
4.24	2.788*
4.23	2.787*
4.23	2.785*
4.23	2.785*
12.0	2.791
12.0	2.790*
13.92	2.7929

* Not shown in figure.

TABLE 52. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD + SILVER ALLOYS (Temperature Dependence) (continued)

DATA SET 24 (cont.)

T	ρ
13.92	2.792*
20.44	2.810
20.44	2.810*
20.45	2.811*
59.17	3.106
81.36	3.303
81.37	3.304*
194.62	4.242
273.10	4.87
293.57	5.035
296.2	5.055*
298.36	5.075

DATA SET 25

T	ρ
1.6	7.076
1.63	7.074*
1.98	7.074
4.23	7.074
4.24	7.073*
4.23	7.073*
4.23	7.073*
4.23	7.073*
12.0	7.078
12.0	7.077*
13.92	7.080
13.92	7.080*
20.44	7.096
20.44	7.096*
20.45	7.096*
59.17	7.374
81.36	7.567
81.37	7.567*
194.62	8.482
273.10	9.100
293.57	9.240
296.2	9.290*
298.36	9.300

DATA SET 26

T	ρ
1.6	9.009
1.63	9.011*
1.98	9.008
4.23	9.009*
4.24	9.009*
4.23	9.009*
4.23	9.010*

DATA SET 26 (cont.)

T	ρ
4.23	9.010*
12.0	9.015
12.0	9.014*
13.92	9.016
13.92	9.016*
20.44	9.030
20.44	9.030*
20.45	9.030*
59.17	9.289
81.36	9.473
81.37	9.473*
194.62	10.365
273.10	10.96
293.57	11.117
296.2	11.138*
298.36	11.153

DATA SET 27

T	ρ
22	8.85
83	9.32
273	10.8*

DATA SET 28

T	ρ
32	6.69
83	7.16
273	8.69

DATA SET 29

T	ρ
273.2	10.99*
373.2	11.90

DATA SET 30*

T	ρ
273.2	10.99
373.2	11.76

DATA SET 31*

T	ρ
273.2	13.89
373.2	13.89

DATA SET 32

T	ρ
273.2	11.24
373.2	11.90*

DATA SET 33*

T	ρ
273.2	10.99
373.2	11.76

DATA SET 34

T	ρ
273.2	9.80
373.2	10.42

DATA SET 35

T	ρ
273.2	7.58
373.2	8.06

DATA SET 36

T	ρ
273.2	5.52
373.2	6.29

DATA SET 37

T	ρ
273.2	3.98
373.2	4.55

DATA SET 38

T	ρ
4.2	6.038
273.2	8.107

DATA SET 39

T	ρ
4.2	2.603
273.2	4.695

DATA SET 40

T	ρ
4.2	1.404
273.2	3.517

DATA SET 41

T	ρ
4.2	0.855
273.2	2.991

DATA SET 42

T	ρ
4.2	0.670

DATA SET 43

T	ρ
4.2	0.370
273.2	2.421*

DATA SET 44

T	ρ
4.2	0.135
273	2.209

DATA SET 45

T	ρ
4.2	8.77
77.0	9.18*
296.0	10.84

DATA SET 46*

T	ρ
4.2	8.75
77.0	9.17
296.0	10.86

DATA SET 47

T	ρ
4.2	2.90

DATA SET 48

T	ρ
4.2	2.71

DATA SET 49

T	ρ
77	8.74
273	9.94

DATA SET 50

T	ρ
77	9.04*
273	10.53

DATA SET 51

T	ρ
4.2	0.584
77	1.067
295	2.836

DATA SET 52

T	ρ
4.2	1.401*
77	1.890
295	3.672

DATA SET 53

T	ρ
4.2	2.801*
77	3.268
295	5.120

DATA SET 54*

T	ρ
4.2	2.788
77	3.275
295	5.113

DATA SET 55

T	ρ
4.2	4.627
77	5.111
295	6.911

DATA SET 56

T	ρ
4.2	6.239
77	6.745
295	8.488

DATA SET 57*

T	ρ
4.2	9.020
77	9.407
295	11.147

DATA SET 58*

T	ρ
1.6	0.0805

DATA SET 59*

T	ρ
1.6	0.0320

DATA SET 60

T	ρ
1.6	0.292

DATA SET 61

T	ρ
76.1	4.817
167.1	5.510
191.3	5.666
273	6.280
274.1	6.293*
289.6	6.417
364.8	6.997

DATA SET 62

T	ρ
90.8	0.956
137.6	1.328
180.9	1.680
199.6	1.827
273	2.429*
290.3	2.565
291	2.548*

DATA SET 63

T	ρ
90.8	1.483
93	1.502
138.1	1.856
173	2.149
199.9	2.339
273	2.949
290.3	3.085
291	3.092*

DATA SET 64

T	ρ
214.3	2.483
253	2.791
273	2.949*
291	3.125*
291.6	3.097*

DATA SET 65*

T	ρ
291	2.823

DATA SET 66

T	ρ
78	1.51

DATA SET 67

T	ρ
310	8.00
373	8.76
423	9.25
473	9.85
523	10.36
573	10.92
623	11.43
673	12.03
723	12.59
773	13.24
823	13.80
873	14.41

* Not shown in figure.

TABLE 52. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD + SILVER ALLOYS (Temperature Dependence) (continued)

T	ρ	T	ρ
DATA SET 67 (cont.)		DATA SET 73	
923	15.11	20.24	7.2119
973	15.68*	90.43	7.7563
1023	16.62	169.33	8.3980
1073	17.36	273	9.1978*
1123	18.18		
1173	18.97	DATA SET 74	
1223	19.64		
1273	20.72	20.24	8.1686
1323	21.60	90.43	8.6426
		169.33	9.1374
DATA SET 68		273	9.9378*
20.24	0.3077		
90.43	0.8819		
169.33	1.5307		
273	2.3713		
DATA SET 69			
20.24	0.6061		
90.43	1.1611		
169.33	1.8063		
273	2.6371		
DATA SET 70			
20.24	0.3591		
90.43	0.9164		
169.33	1.5709		
273	2.4167*		
DATA SET 71			
20.24	0.3809		
90.43	0.9406		
169.33	1.5961		
273	2.4441*		
DATA SET 72			
20.24	0.8763		
90.43	1.4434		
169.33	2.0930		
273	2.9302*		

* Not shown in figure.

TABLE 53. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER + GOLD ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Au	Composition (continued), Specifications, and Remarks
1	307	Weinberg, I.	1967	A	4.2-295			0.38	Calculated composition (0.21 a/o Au), solute concentration determined by chemical analysis; 99.999 Ag from Cominco and 99.999 Au from American Smelting and Refining Co. melted in previously outgassed, high purity graphite crucibles by induction heating under a dynamic vacuum of 10^{-6} Torr; shaken vigorously for 1 h, billets inverted and a similar melting cycle repeated, homogenized at 873 K for 6 d under 10^{-6} Torr vacuum, swaged to 0.070 in and drawn through diamond die to final diam of 0.010 in with frequent etchings with mixture of ammonium hydroxide and hydrogen peroxide, and finally annealed at 953 K for 24 h; data extracted from table.
2	307	Weinberg, I.	1967	A	4.2-295			0.51	Calculated composition (0.28 a/o Au); similar to the above specimen.
3	307	Weinberg, I.	1967	A	4.2-295			0.84	Calculated composition (0.46 a/o Au); similar to the above specimen.
4	307	Weinberg, I.	1967	A	4.2-295			2.7	Calculated composition (1.5 a/o Au); similar to the above specimen.
5	300	Boes, J., Van Dam, A.J., and Bijovet, J.	1968		0.94-13			28.6	Calculated composition (18 a/o Au); strip specimen 30 x 1 x 1 mm; prepared by arc melting in argon and rolling; annealed for 1 h at 1073 K in vacuum and quenched; data read from figure.
6*	300	Boes, J., et al.	1968		1.0-13				Similar to the above specimen but 0.10 Yb (0.07 a/o) added.
7*	300	Boes, J., et al.	1968		1.1-14				The above specimen annealed at 1073 K and quenched.
8	300	Boes, J., et al.	1968		4.2, 77			16.9	Calculated composition (10 a/o Au); similar to the specimen of data set number 5 above but data extracted from table.
9	300	Boes, J., et al.	1968		4.2, 77			31.3	Calculated composition (20 a/o Au); similar to the above specimen.
10	300	Boes, J., et al.	1968		4.2, 77			43.9	Calculated composition (30 a/o Au); similar to the above specimen.
11	302	Iyer, V.K. and Asimow, R.M.	1967		290-1147			8.8	Calculated composition (5 a/o Au), less than 0.1 total impurity with 0.05 Si indicated by spectrographic analysis; 99.999 Ag and Au melted in graphite crucible in Ar, evaporation of Ag resulted in composition change of less than 0.2 a/o; 0.125 in diam ingots swaged to 0.040 in and drawn to 0.010 in; annealed in Ar; maintained in Ar above 673 K to prevent evaporation of Ag but measured in vacuum, different specimen measured in 273-303 K range than at higher temperatures, identical values obtained for at least two heating cycles; uncertainty in temperature ± 0.3% T (in °C), standard deviation of points from best fitted curve less than 0.5% of the mean, resistivity accurate to within 2% with error mainly due to length and density uncertainty; data corrected for thermal expansion; data read from figure.
12	302	Iyer, V.K. and Asimow, R.M.	1967		275-1147			16.9	Calculated composition (10 a/o Au); similar to the above specimen.
13	302	Iyer, V.K. and Asimow, R.M.	1967		276-1158			43.9	Calculated composition (30 a/o Au); similar to the above specimen.
14	127	Roll, A. and Motz, H.	1957	E	1286-1461			47.7	Calculated composition (33.3 a/o Au); measured in liquid state; prepared from 99.995 pure Ag and 99.95 pure Au; $d\rho/dT = 0.0154 \times 10^{-8}\ \Omega m\ K^{-1}$; ± 1% uncertainty in resistivity; data read from figure.
15	127	Roll, A. and Motz, H.	1957	E	1282-1461			43.9	Calculated composition (30 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0137 \times 10^{-8}\ \Omega m\ K^{-1}$.

* Not shown in figure.

TABLE 53. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER + GOLD ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Au	Composition (continued), Specifications, and Remarks
16	127	Roll, A. and Motz, H.	1957	E	1279-1463			41.5	Calculated composition (28 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0134 \times 10^{-8}\ \Omega m\ K^{-1}$.
17	127	Roll, A. and Motz, H.	1957	E	1277-1463			39.1	Calculated composition (26 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0153 \times 10^{-8}\ \Omega m\ K^{-1}$.
18	127	Roll, A. and Motz, H.	1957	E	1275-1463			37.2	Calculated composition (24.5 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0138 \times 10^{-8}\ \Omega m\ K^{-1}$.
19	127	Roll, A. and Motz, H.	1957	E	1273-1462			35.3	Calculated composition (23 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0126 \times 10^{-8}\ \Omega m\ K^{-1}$.
20	127	Roll, A. and Motz, H.	1957	E	1257-1462			20.7	Calculated composition (12.5 a/o Au); similar to the above specimen but with $d\rho/dT = 0.0100 \times 10^{-8}\ \Omega m\ K^{-1}$.
21	297	Giauque, W.F. and Stout, I.W.	1938	A	1.6-298	No. 2	56.08		Drawn wire 0.579 mm in diam and about 100 cm long; annealed by heating to redness in a flame during and after drawing, wound loosely on a spool in insulated layers, and again annealed at 383 K for about 15 h; measured in four cooling cycles over period of 2.5 years; resistance ratio as a function of temperature and *specific resistance at 273 K reported, from* which resistivity was calculated by CINDAS, without correcting for thermal expansion; resistance accurate to 0.01%; data extracted from table.
22	297	Giauque, W.F. and Stout, I.W.	1938	A	1.6-298	No. 1	83.12		Similar to the above specimen.
23	128	Grüneisen, E. and Reddemann, H.	1934		22-273	4		0.67	Calculated composition (0.37 a/o Au); wire specimen; data extracted from table.
24	128	Grüneisen, E. and Reddemann, H.	1934		22-273	5		37.8	Calculated composition (25 a/o Au); single crystal wire specimen; data extracted from table.
25	130	Sedstrom, E.	1919		273, 373			8.78	Calculated composition (5.0 a/o Au); wire specimen rolled and drawn to thickness of 1 mm and annealed at temperature near the melting point for 0.5 h; data extracted from table.
26	130	Sedstrom, E.	1919		273, 373			16.4	Calculated composition (9.7 a/o Au);
27	130	Sedstrom, E.	1919		273, 373			23.66	Calculated composition (14.5 a/o Au);
28	130	Sedstrom, E.	1919		273, 373			31.37	Calculated composition (20.0 a/o Au);
29	130	Sedstrom, E.	1919		273, 373			44.16	Calculated composition (30.2 a/o Au);
30*	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			0.164	Composition (0.09 a/o Au) estimated by using Nordheim's rule and the values of residual resistivity per atomic percent solute reported by J.O. Linde (Ph.D. Thesis, University of Stockholm, 1939); 1 mm diam wire specimens prepared from 99.9999 Ag and 99.999 or 99.9999 Au were supplied in three batches by Cambridge Metals Research Ltd; similar specimens analyzed for Fe content by D.S. Russell, Division of Applied Chemistry, N.R.C. of Canada showed 1.7 to 9.0 atomic ppm of Fe; specimen as received was drawn down, etched, washed in distilled water and alcohol, dried, sealed in quartz capsule with 0.33 atm oxygen to minimize Fe contamination, and annealed at 1173 K for 72 h; uncertainty in temperature less than 0.05 K at all temperatures, 1% error in absolute resistivity; measurement temperature of residual resistivity not stated, assumed to be 4.2 K; data extracted from table.

* Not shown in figure.

TABLE 53. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER + GOLD ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Au	Composition (continued), Specifications, and Remarks
31	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			1.25	Estimated composition (0.69 a/o Au); similar to the above specimen.
32	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			1.43	Estimated composition (0.79 a/o Au); similar to the above specimen.
33	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			2.47	Estimated composition (1.37 a/o Au); similar to the above specimen.
34	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			2.97	Estimated composition (1.65 a/o Au); similar to the above specimen.
35	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			3.95	Estimated composition (2.2 a/o Au); similar to the above specimen.
36	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			9.27	Estimated composition (5.3 a/o Au); similar to the above specimen.
37	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			9.94	Estimated composition (5.7 a/o Au); similar to the above specimen.
38*	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			16.9	Estimated composition (10 a/o Au); similar to the above specimen.
39	298	Crisp, R.S. and Rungis, J.	1970	A	4.2, 273			40.3	Estimated composition (27 a/o Au); similar to the above specimen.
40	135	Huray, P.G., Roberts, L.D., and Thomson, J.O.	1971		4.2-296	Ag_3Au	62.16	37.84	Calculated composition (25 a/o Au), chemical analysis by Johnson Matthey Chemicals Ltd. of similar specimens indicated composition uncertainty of 0.5 a/o; foil specimen 0.0508 mm (2 mil) thick and uniform to at least 1%; 99.99 Ag and Au arc-melted and cooled in Ar several times and drop cast into water cooled cylindrical mold, cylinders annealed in inert atmosphere for 5 d within 50 K of melting point, strips cut lengthwise from cylinder and rolled to final thickness with intermittent annealing; finally annealed for 100 h at 641 K, furnace cooled to 523 K, maintained at 523 K for 120 h, and quenched in room temperature water; uncertainty in thickness less than 1%; uncertainties in resistivity ± 0.07, ± 0.07, and $\pm 0.08 \times 10^{-8}$ Ωm at 4.2, 77, and 296 K respectively; data extracted from table.
41	135	Huray, P.G., et al.	1971		4.2-296	Ag_3Au	62.16	37.84	Similar to the above specimen except finally suspended in vacuum furnace at 873 K for 30 min or more, then dropped in vacuum into room temperature bath of vacuum-pump oil.
42	308	Barber, A.J. and Caplin, A.D.	1975	A	4.26-8.83	Sample 63		1.67	Calculated, nominal composition (0.92 a/o Au); wire specimen 0.45 mm in diam; high purity Ag and Au melted together in quartz ampoules, homogenized, and rolled and drawn into wire; annealed at about 873 K for 6-10 h in a sealed capsule containing up to 10 Torr oxygen or in a continuous flow of oxygen at 10^{-1} Torr in order to precipitate Fe and remove resistance minimum; measured in helium environments residual resistivity 0.3470×10^{-8} Ωm; uncertainty in temperature less than ± 200 mK below 20 K and ± 100 mK below 10 K, less than 1% uncertainty in geometrical factor; data read from figure.

* Not shown in figure.

TABLE 53. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER + GOLD ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Au	Composition (continued), Specifications, and Remarks
43	308	Barber, A.J. and Caplin, A.D.	1975	A	4.25-18.75	Sample 38		0.64	Similar to the above specimen; calculated, nominal composition (0.35 a/o Au); (0.62 mm diam); residual resistivity 0.1230 x 10^{-8} Ωm.
44	308	Barber, A.J. and Caplin, A.D.	1975	A	4.24-18.71	Sample 37		0.33	Similar to the above specimen; calculated, nominal composition (0.18 a/o Au); (0.45 mm diam); residual resistivity 0.0650 x 10^{-8} Ωm.
45*	308	Barber, A.J. and Caplin, A.D.	1975	A	4.27-18.92	Sample 36		0.13	Similar to the above specimen; calculated, nominal composition (0.07 a/o Au); (0.40 mm diam); residual resistivity 0.0314 x 10^{-8} Ωm.
46*	308	Barber, A.J. and Caplin, A.D.	1975	A	4.27-19.05	Sample 35		0.064	Similar to the above specimen; calculated, nominal composition (0.035 a/o Au); (0.38 mm diam); residual resistivity 0.0156 x 10^{-8} Ωm.
47*	308	Barber, A.J. and Caplin, A.D.	1975	A	3.13-19.59	Sample 51		0.033	Similar to the above specimen; calculated, nominal composition (0.018 a/o Au); (0.15 mm diam); residual resistivity 0.00858 x 10^{-8} Ωm.
48	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2-295		96.41	3.59	Calculated composition (2.0 a/o Au); parallelopiped specimen 0.100 x 0.100 x 1.25 in; 99.999+ pure Ag and Au induction melted in helium; cast in ingots, cold worked, etched in 10% KCN, homogenized at 1073 K for 72 h, and quenched in cold water; specimen machined from axial section of ingot using tungsten carbide tools and KCN etching to avoid ferromagnetic contaminants; finally heated at 1073 K for 72 h and quenched; measurements at ambient temperature were reported as being at 295 ± 3 K; uncertainty in resistivity 1.5%; data extracted from table.
49*	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2-295		83.13	16.87	Calculated composition (10.0 a/o Au); similar to the above specimen.
50	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2-295		68.66	31.34	Calculated composition (20.0 a/o Au); similar to the above specimen.
51*	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2-295		56.10	43.90	Calculated composition (30.0 a/o Au); similar to the above specimen.
52	309	Sparks, L.L. and Hust, J.G.	1972		4			41.5	0.00020 Fe, 0.00020 Si, 0.00005 Al, 0.00005 Ca, 0.00005 M, 0.00003 Pb, and 0.00002 Ni, calculated composition (28 a/o Au); cast in billets 2.5 cm in diam, swaged to 0.6 cm diam, drawn to 0.06 cm with carbon dies, and finally drawn to 0.020 cm wire with diamond dies; no lubrication, annealing, or etching during drawing process; annealed at 673 K for 1 h; ± 3% uncertainty in resistivity; data read from figure.
53	309	Sparks, L.L. and Hust, J.G.	1972		4			22.2	Calculated composition (13.5 a/o Au); no details reported.
54	38	Linde, J.O.	1932		89.3-293			1.65	Calculated composition (0.91 a/o Au); Kahlbaum Ag and Heraeus Au melted together in 3 x 40 mm quartz tubes, homogenized, drawn through sapphire die to about 0.75 mm diam, and annealed in vacuum at 773 K for 5-10 h; data extracted from table.
55	38	Linde, J.O.	1932		89.6-293			3.63	Calculated composition (2.02 a/o Au); similar to the above specimen.
56	38	Linde, J.O.	1932		94.5-290			5.38	Calculated composition (3.02 a/o Au); similar to the above specimen.
57	38	Linde, J.O.	1932		291			0.960	Calculated composition (0.528 a/o Au); similar to the above specimen.
58*	38	Linde, J.O.	1932		291			2.83	Calculated composition (1.57 a/o Au); similar to the above specimen.

* Not shown in figure.

TABLE 53. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER + GOLD ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Au	Composition (continued), Specifications, and Remarks
59	305	Dawson, H.I.	1965	A	78				Calculated composition (15.4 a/o Au), impurity concentration a few times 10^{-4}; 0.20 or 0.25 mm diam wire; approximate grain size 0.02 mm; annealed at 723 K for 1 h under vacuum of 10^{-5} mm Hg; measured in stirred liquid nitrogen; smallest detectable change in resistivity less than 10^{-12} Ωm; data extracted from table.
60	310	Van Baarle, C., Gorter, F.W., and Winsemius, P.	1967		4.2			0.75	Calculated composition (0.41 a/o Au); prepared from Tadanac High Purity Silver from Consolidated Mining and Smelting Company of Canada, Ltd of 99.9999 nominal purity; spectrographic analysis by supplier showed 1 ppm Si and less than 0.1 ppm Fe, Ca, and Mg; ingots of diam 0.3 cm and several centimeters long prepared with slow solidification and low cooling rate; axial homogeneity checked by measuring resistivity of samples from both ends of ingot; annealed in vacuum at 823 K for 24 h; resistivities reported as ρ_0, assumed to be measured at 4.2 K; data extracted from table.
61	310	Van Baarle, C., et al.	1967		4.2			2.28	Similar to the above specimen; calculated composition (1.26 a/o Au); annealed at 848 K in vacuum for 48 h.
62	310	Van Baarle, C., et al.	1967		4.2			5.21	Similar to the above specimen; calculated composition (2.92 a/o Au); annealed at 848 K in vacuum for 48 h.
63	310	Van Baarle, C., et al.	1967		4.2				The above specimen strained 10%.

TABLE 54. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF SILVER + GOLD ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

DATA SET 1

T	ρ
4.2	0.07
77.3	0.35
273.0	1.52
295.0	1.65

DATA SET 2

T	ρ
4.2	0.10
77.3	0.38
273.0	1.54
295.0	1.67

DATA SET 3

T	ρ
4.2	0.16
77.3	0.44
273.0	1.62
295.0	1.76

DATA SET 4

T	ρ
4.2	0.50
77.3	0.81
273.0	1.99
295.0	2.13

DATA SET 5

T	ρ
0.94	5.36345*
2.40	5.36325
2.40	5.36304*
2.91	5.36298
4.13	5.36280
4.13	5.36260*
7.16	5.36298
7.24	5.36260
7.60	5.36260
7.71	5.36268
7.92	5.36257
8.13	5.36283
8.33	5.36275
8.57	5.36275
8.72	5.36274
8.96	5.36275
10.14	5.36329
10.81	5.36343

DATA SET 5 (cont.)

T	ρ
11.10	5.36324
11.26	5.36364*
12.26	5.36422
13.20	5.36489

DATA SET 6*

T	ρ
1.02	5.6194
2.42	5.6170
2.92	5.6165
4.13	5.6157
4.13	5.6155
7.54	5.6144
7.66	5.6143
7.90	5.6142
8.06	5.6143
8.24	5.6143
8.49	5.6142
8.65	5.6141
8.88	5.6141
10.07	5.6143
10.49	5.6144
11.00	5.6144
12.00	5.6148
12.63	5.6151

DATA SET 7*

T	ρ
1.07	5.7447
1.92	5.7404
2.95	5.7367
3.60	5.7356
4.21	5.7338
4.21	5.7335
4.48	5.7335
4.59	5.7335
4.71	5.7331
4.90	5.7328
5.13	5.7324
5.38	5.7321
5.49	5.7320
5.49	5.7318
5.75	5.7317
5.98	5.7315
6.15	5.7312
6.38	5.7311

DATA SET 7 (cont.)*

T	ρ
6.54	5.7310
6.77	5.7308
6.95	5.7306
7.15	5.7305
7.38	5.7304
7.59	5.7303
7.84	5.7302
8.16	5.7303
8.45	5.7303
8.86	5.7303
9.34	5.7303
9.76	5.7303
10.32	5.7301
10.66	5.7299
11.28	5.7300
11.79	5.7302
12.47	5.7303
12.91	5.7306
13.46	5.7310
13.85	5.7313
14.32	5.7315

DATA SET 8

T	ρ
4.2	3.32
77	3.66

DATA SET 9

T	ρ
4.2	5.82
77	6.22

DATA SET 10

T	ρ
4.2	7.65
77	8.05

DATA SET 11

T	ρ
290	3.40
352	3.77
376	3.91
424	4.21
464	4.44
512	4.74
565	5.09

DATA SET 11 (cont.)

T	ρ
632	5.54
663	5.75
733	6.40
792	6.66
846	7.09
875	7.31
964	7.96
1044	8.60
1074	8.85
1116	9.19
1147	9.58

DATA SET 12

T	ρ
275	4.89
304	5.08
359	5.40
471	6.17
519	6.48
537	6.56
572	6.85
612	7.11
642	7.35
665	7.65
719	7.96
766	8.17
801	8.49
839	8.79
880	9.10
923	9.49
961	9.71
1024	10.21
1065	10.52
1127	11.11
1147	11.19

DATA SET 13

T	ρ
276	9.50
297	9.62
399	10.39
435	10.64
535	11.37
550	11.54
573	11.62
667	12.35

DATA SET 13 (cont.)

T	ρ
707	12.70
763	13.25
827	13.68
877	14.10
903	14.33
931	14.56
965	14.88
985	15.01
1011	15.24
1054	15.74
1096	16.13
1141	16.61
1158	16.83

DATA SET 14

T	ρ
1286	31.3
1321	31.7*
1341	37.2
1360	32.6*
1381	32.8*
1401	33.2
1420	33.4*
1440	33.6*
1461	34.1

DATA SET 15

T	ρ
1282	30.0
1302	30.0*
1322	30.3*
1341	30.6
1360	30.9*
1381	31.2*
1400	31.5
1420	31.7*
1441	32.0*
1461	32.3

DATA SET 16

T	ρ
1279	30.1*
1284	30.2*
1304	30.5
1323	30.7*
1343	31.1*

DATA SET 16 (cont.)

T	ρ
1363	31.4
1383	31.5*
1404	31.7*
1423	32.3*
1442	32.5
1463	32.8*

DATA SET 17

T	ρ
1277	28.9
1285	28.9*
1304	29.4*
1324	29.6*
1342	29.9
1363	30.3*
1383	30.5*
1402	30.8
1424	31.2*
1443	31.5*
1463	31.8

DATA SET 18

T	ρ
1275	28.9*
1285	29.0*
1304	29.3*
1323	29.5
1343	29.9*
1363	30.4*
1383	30.4
1403	30.7*
1422	31.1*
1442	31.3
1463	31.7*

DATA SET 19

T	ρ
1273	27.6
1285	27.8*
1303	28.1*
1323	28.3*
1342	28.7
1363	28.9*
1383	29.2*
1402	29.3
1422	29.6*

* Not shown in figure.

TABLE 54. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF SILVER + GOLD ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 19 (cont.)	
1442	29.8*
1462	30.1
DATA SET 20	
1257	22.9
1295	23.1*
1304	23.3*
1323	23.7*
1343	23.9
1363	24.0*
1382	24.4*
1403	24.5
1423	24.8*
1443	24.9*
1462	25.2
DATA SET 21	
1.6	7.677
1.63	7.674*
1.98	7.673
4.23	7.673*
4.24	7.673*
4.23	7.675*
4.23	7.674*
4.23	7.674*
12.0	7.678
12.0	7.677*
13.92	7.679
13.92	7.679*
20.44	7.690
20.44	7.692*
20.45	7.689*
59.17	7.922
81.36	8.095
81.37	8.093*
194.62	8.920
273.10	9.48
293.57	9.628
296.2	9.645*
298.36	9.660*
DATA SET 22	
1.6	3.400
1.63	3.398*
1.98	3.402
DATA SET 22 (cont.)	
4.23	3.403
4.24	3.400*
4.23	3.397*
4.23	3.398*
4.23	3.398*
12.0	3.405
12.0	3.406*
13.92	3.407
13.92	3.406*
20.44	3.417
20.44	3.416*
20.45	3.416*
59.17	3.622
81.36	3.781
81.37	3.782*
194.62	4.553
273.10	5.06
293.57	5.195
296.2	5.213*
298.36	5.224
DATA SET 23	
22	0.163
83	0.473
273	1.63*
DATA SET 24	
22	6.87
83	7.25
273	8.57
DATA SET 25	
273.2	3.41
373.2	4.13
DATA SET 26	
273.2	5.13*
373.2	6.25
DATA SET 27	
273.2	6.80
373.2	7.41
DATA SET 28	
273.2	8.00
373.2	8.70
DATA SET 29	
273.2	9.71
373.2	10.31
DATA SET 30*	
4.2	0.033
273.2	1.532
DATA SET 31	
4.2	0.249
273.2	1.758
DATA SET 32	
4.2	0.285
273.2	1.788
DATA SET 33	
4.2	0.493
273.2	2.052
DATA SET 34	
4.2	0.593
273.2	2.126
DATA SET 35	
4.2	0.768
273.2	2.507
DATA SET 36	
4.2	1.813
273.2	3.408*
DATA SET 37	
4.2	1.923
273.2	3.581
DATA SET 38*	
4.2	3.303
273.2	4.958
DATA SET 39	
4.2	7.084
273.2	8.874
DATA SET 40	
4.2	6.73
77.0	7.10
296.0	8.62
DATA SET 41	
4.2	6.69
77.0	7.05*
296.0	8.59*
DATA SET 42	
4.26	0.3470
4.67	0.3470
5.46	0.3471
6.24	0.3471
6.84	0.3472
7.36	0.3472
8.11	0.3473
8.83	0.3474
DATA SET 43	
4.25	0.1230
4.53	0.1230
4.95	0.1230
5.53	0.1231
5.94	0.1231
7.05	0.1232
9.68	0.1235
10.38	0.1237
10.38	0.1237*
11.48	0.1240
12.85	0.1246
13.84	0.1252
14.89	0.1259
15.89	0.1266
DATA SET 43 (cont.)	
16.87	0.1275
18.75	0.1296
DATA SET 44	
4.24	0.06502
4.24	0.06502*
4.47	0.06502
4.89	0.06503
5.53	0.06506
5.90	0.06507
6.90	0.06513
7.53	0.06519
9.42	0.06544
10.28	0.06563
11.40	0.06592
12.82	0.06643
14.00	0.06700
14.00	0.06695*
14.76	0.06745
15.85	0.06824
16.79	0.06890
18.71	0.07078
DATA SET 45*	
4.27	0.03142
4.27	0.03142
4.46	0.03142
4.89	0.03143
5.45	0.03145
5.89	0.03147
6.87	0.03152
7.46	0.03156
9.29	0.03177
10.26	0.03195
10.26	0.03194
11.53	0.03224
11.53	0.03223
12.88	0.03264
14.22	0.03326
14.22	0.03321
14.96	0.03362
16.11	0.03426
16.14	0.03432
16.94	0.03479
16.98	0.03487
18.92	0.03655
18.92	0.03648
DATA SET 46*	
4.27	0.01561
4.27	0.01561
4.84	0.01562
5.47	0.01564
5.83	0.01565
6.78	0.01569
7.38	0.01573
9.10	0.01588
10.19	0.01603
10.19	0.01602
11.61	0.01629
11.61	0.01628
12.88	0.01662
12.88	0.01660
14.32	0.01712
15.10	0.01742
15.10	0.01739
16.11	0.01794
16.11	0.01790
17.02	0.01851
17.02	0.01842
19.05	0.01996
19.05	0.01982
DATA SET 47*	
3.13	0.008583
3.40	0.008584
3.76	0.008586
4.03	0.008589
4.25	0.008590
4.30	0.008591
4.49	0.008593
4.63	0.008595
4.82	0.008599
4.98	0.008602
5.22	0.008606
5.52	0.008613
6.01	0.008630
7.01	0.008664
7.89	0.008718
8.59	0.008762
9.18	0.008813
9.77	0.008877
10.28	0.008952
11.19	0.009076
12.22	0.009258
13.18	0.009498

* Not shown in figure.

TABLE 54. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF SILVER + GOLD ALLOYS (Temperature Dependence) (continued)

T	ρ	T	ρ
DATA SET 47 (cont.)*		DATA SET 55	
14.32	0.009822	89.6	1.113
15.35	0.01018	122.1	1.322
16.41	0.01066	138.7	1.423
17.26	0.01117	248.5	2.100
18.75	0.01198	273	2.250
19.59	0.01268	292.6	2.363*
DATA SET 48		DATA SET 56	
4.2	0.736	94.5	1.493
77	1.047	125.0	1.678
295	2.375	153.0	1.856
DATA SET 49		256.9	2.494
4.2	3.360	273	2.594
77	3.668	290.2	2.697
295	5.135	DATA SET 57	
DATA SET 50		291	1.781
4.2	5.835*	DATA SET 58*	
77	6.199*	291	2.158
295	7.723	DATA SET 59	
DATA SET 51		78	5.13
4.2	7.774	DATA SET 60	
77	8.127	4.2	0.140
295	9.747	DATA SET 61	
DATA SET 52		4.2	0.408
4	6.97	DATA SET 62	
DATA SET 53		4.2	0.97
4	4.05	DATA SET 63	
DATA SET 54		4.2	0.99
89.3	0.731		
97.4	0.771		
138.1	1.026		
262.5	1.784		
273	1.827		
292.6	1.962		

* Not shown in figure.

AD-A129 161 ELECTRICAL RESISTIVITY OF TEN SELECTED BINARY ALLOY SYSTEMS(U) THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER LAFAYETTE IN C Y HO ET AL. APR 81 CINDAS-59

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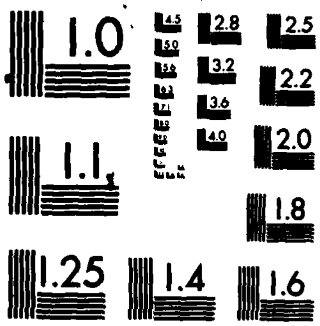


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

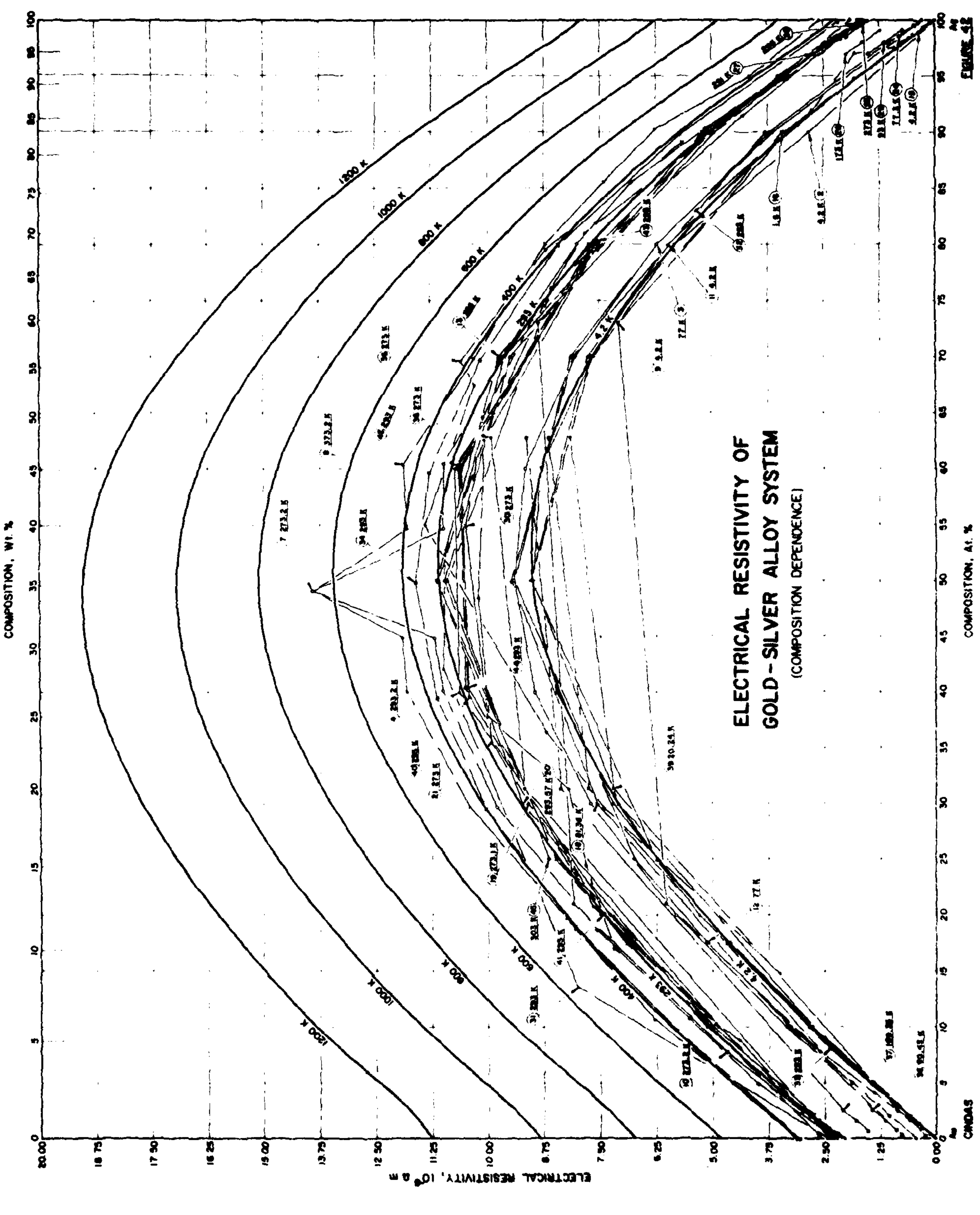

ELECTRICAL RESISTIVITY OF
GOLD-SILVER ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION, Wt. %
COMPOSITION, At. %
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
1200 K
1000 K
800 K
600 K
400 K
CINDAS
FIGURE 42

TABLE 55. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF *GOLD–SILVER* ALLOY SYSTEM (Composition Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Ag)	Composition (weight percent), Specifications, and Remarks
1*	311	Howe, R.A. and Enderby, J.E.	1967	A	1408	0–100	Liquid alloys prepared from 99.999 pure Ag and Au supplied by Koch-Light by melting under Ar; fused quartz sample holders, 0.003 in Mo foil contacts coated with colloidal graphite to prevent contamination; no more than 0.01 a/o Mo was dissolved by sample and there was no visual evidence of the quartz cells being attacked by the samples except in case of the 90 a/o Ag alloy which was heated to above 1453 K; simultaneous thermopower and resistivity measurements; data read from figure.
2	300	Boes, J., Van Dam, A.J., and Bijovet, J.	1968		4.2	0–100	Strip specimens 30 x 1 x 1 mm; prepared by arc-melting in Ar and rolling; annealed for 1 h at 1073 K in vacuum and quenched; data extracted from table.
3	300	Boes, J., et al.	1968		77	0–100	The above specimens.
4	312	Ricker, T.	1963	V	293.2	0–100	Alloys prepared from 99.99+ pure metals by arc-melting; homogenized at 673 K for 1 h; data extracted from table.
5*	127	Roll, A. and Motz, H.	1957	R	1373	0–100	Alloys in liquid state; prepared from 99.995 pure silver and 99.95 pure gold; ± 1% uncertainty in resistivity; data read from figure.
6*	127	Roll, A. and Motz, H.	1957	R	1473	0–100	The above specimens.
7	130	Sedström, E.	1919		273.2	0–100	Wire specimens 1 mm thick; rolled and drawn; heated at near melting point for 30 min; data extracted from table.
8	130	Sedström, E.	1919		373.2	0–100	The above specimens.
9	298	Crisp, R.S. and Rungis, J.	1970	A	4.2	0.15–100	Compositions estimated by using Nordheim's rule and the values of residual resistivity per atomic percent solute reported by J.O. Linde (Ph.D. Thesis, University of Stockholm, 1939); 1 mm diam wire specimens prepared from 99.9999 Ag and 99.999 or 99.9999 Au were supplied in three batches by Cambridge Metals Research Ltd.; some specimens analyzed for Fe content showed 1.7 to 9.0 atomic ppm of Fe; specimens as received were drawn down, etched, washed in distilled water and alcohol, dried, sealed in quartz capsules with 0.33 atm oxygen to minimize Fe contamination, and annealed at 1173 K for 72 h; uncertainty in temperature less than 0.05 K, 1% error in absolute resistivity; measurement temperature of residual resistivity not stated, assumed to be 4.2 K; data extracted from table.
10	298	Crisp, R.S. and Rungis, J.	1970	A	273.2	0.15–100	The above specimens.
11	299	Davis, T.H. and Rayne, J.A.	1972	A	4.2	0–100	Parallelopiped specimens 0.100 x 0.100 x 1.25 in; 99.999+ pure Ag and Au induction melted in helium; cast in ingots, cold worked, etched in 10% KCN, homogenized at 1073 K for 72 h and quenched in cold water; specimen machined from axial section of ingot using tungsten carbide tools and KCN etching to avoid ferromagnetic contaminants; finally heated at 1073 K for 72 h and quenched; uncertainty in resistivity ± 1.5%; authors reported residual resistivity of 0.298×10^{-8} Ωm for 1 a/o Ag in Au and of 0.375×10^{-8} Ωm for 1 a/o Au in Ag; data extracted from table.
12	299	Davis, T.H. and Rayne, J.A.	1972	A	77	0–100	The above specimens measured at 77 K.
13	299	Davis, T.H. and Rayne, J.A.	1972	A	295	0–100	The above specimens measured at 295 ± 3 K.

* Not shown in figure.

TABLE 55. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD-SILVER ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Ag)	Composition (weight percent), Specifications, and Remarks
14*	301	Stewart, R.G. and Huebener, R.P.	1970	A	1.6	0.25–0.94	Polycrystalline wire specimens 10 mil in diam; concentrations determined by wet chemical and neutron activation analyses; minor constituent impurities about 2 ppm; supplied by Cominco American, Inc. and Sigmund Cohn, Inc.; rinsed in dilute nitric acid prior to spot welding to sample holder; annealed by Joule heating in air starting at 1223 K and ending with 24 h at 1023 K; cooled to room temperature within 1 h; temperatures accurate to within 0.25 K, geometric factor to 0.5%; thermal expansion correction neglected; data extracted from table.
15	29	Dugdale, J.S. and Basinski, Z.S.	1967	A	4.2	99.0–99.9	Rod specimens 1 mm in diam and 15 cm long; 99.999 Ag from American Smelting and Refining Co. and 99.99+ Au from Canadian Mint melted together in sealed quartz tube and quenched; homogenized at 1213 K for 3 weeks; ingots drawn to required diam and annealed at 823 K for 18 h in close fitting Pyrex tubes; 0.365×10^{-8} Ωm residual resistivity per atomic percent solute reported for Au in Ag, accurate to better than 1%; deviations from Matthiessen's rule reported from 4.2 K to room temperature; resistivity uncertainty ± 0.1%; data read from figure.
16	297	Giauque, W.F. and Stout, J.W.	1938	A	1.6	0.2–90	Drawn wires 0.579 mm in diam and about 1 m long; annealed by heating to redness in a flame during and after drawing, wound loosely on spool in insulated layers, and again annealed at 383 K for about 15 h; measured in four cooling cycles over period of 2.5 years; resistance ratio as function of temperature and specific resistance at 273 K reported, from which resistivity was calculated by CINDAS, without correcting for thermal expansion; resistance accurate to 0.01%, resistivity to 1%; data extracted from table.
17*	297	Giauque, W.F. and Stout, J.W.	1938	A	12.0	0.2–90	The above specimens.
18	297	Giauque, W.F. and Stout, J.W.	1938	A	81.36	0.2–90	The above specimens.
19	297	Giauque, W.F. and Stout, J.W.	1938	A	273.1	0.2–90	The above specimens.
20	297	Giauque, W.F. and Stout, J.W.	1938	A	293.57	0.2–90	The above specimens.
21*	313	Beckmann, B.	1911		273	2.1–98.05	Original document not available; data, without measurement information, extracted from International Critical Tables of Numerical Data, Physics, Chemistry and Technology, Vol. 6, McGraw-Hill Book Co., p. 160, 1929.
22*	308	Barber, A.J. and Caplin, A.D.	1975	A	0	99.08–99.982	Wire specimens; high purity Ag and Au melted together in quartz ampoules, homogenized, and rolled and drawn into wire; annealed at 873 K for 6–10 h in a sealed capsule containing up to 10 Torr oxygen or in a continuous flow of oxygen at 10^{-1} Torr in order to precipitate Fe; uncertainty in temperature less than ± 200 mK below 20 K and ± 100 mK below 10 K; uncertainty in geometrical factor less than 1%; resistivity measured down to 1.5 K and extrapolated to 0 K if necessary; data extracted from table.
23*	307	Weinberg, I.	1967	A	4.2	98.5–99.95	Compositions determined by chemical analysis; wire specimens 0.010 in. in diam; 99.999 Ag from Cominco and 99.999 Au from American Smelting and Refining Co. melted under dynamic vacuum of 10^{-6} Torr in previously outgassed, high purity graphite crucibles by induction heating, shaken vigorously for 1 h; billets inverted and a similar melting cycle repeated; ingot given a homogenizing anneal at 873 K for 6 days under vacuum of 10^{-6} Torr, swaged to 0.070 in and drawn through diamond die to final diameter; etched frequently during drawing and swaging with mixture of ammonium hydroxide and hydrogen peroxide; final anneal at 953 K for 24 h; temperature and voltage measurements accurate to 0.1 K and 0.01 μV respectively; data extracted from table.

* Not shown in figure.

TABLE 55. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD-SILVER ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Ag)	Composition (weight percent), Specifications, and Remarks
24	307	Weinberg, I.	1967	A	77.3	98.5-99.95	The above specimens.
25	307	Weinberg, I.	1967	A	273	98.5-99.95	The above specimens.
26	307	Weinberg, I.	1967	A	295	98.5-99.95	The above specimens.
27	38	Linde, J.O.	1932		291	96.98-99.09	Kahlbaum Ag and Heraeus Au melted together in 3 x 40 mm quartz tubes, homogenized, drawn through sapphire dies to about 0.75 mm diam, and annealed in vacuum at 773 K for 5-10 h; data extracted from table.
28	38	Linde, J.O.	1932		173	96.98-99.09	The above specimens.
29	38	Linde, J.O.	1932		93	96.98-99.09	The above specimens.
30	314	Broniewski, W. and Wesolowski, K.	1932		273	0-99.2	Components melted in vacuum in high frequency furnace; ingots tempered at 1073 K for 50 h, reduced to 5 mm diam wires and tempered at 823 K for 1 h; conductivity reported in figure in incorrect units of Ωcm^{-2}.
31	315	Shimizu, Y.	1932		293	0-100	Purest metals from Kahlbaum melted in silica tube in electric furnace; mixed and cast in rods 8 mm thick and 8 cm long in an iron mold the inner surface of which was coated with caolin; then melted and annealed in vacuo in silica tubes; to avoid iron contamination, surfaces treated with dilute hydrochloric or sulphuric acid, washed with water, and dried in absolute alcohol; drawn to wire 0.82 mm thick and again annealed before measurement; measurement temperature not stated explicitly, assumed to be 293 K; densities before and after expelling absorbed gases also measured; data extracted from table.
32	316	Linde, J.O.	1968	B		83-99	Components melted in sealed silica tubes, slightly cold-rolled, and homogenized by annealing for some hours at high temperatures; drawn into wires and measured in cold worked state as well as after annealing in the 673-873 K range; measured at 293 K; data reported as $\Delta\rho/c$ where $\Delta\rho$ is the difference between the resistivity values of the alloys and that of the pure base metal at 293 K and c is the atomic concentration; the $\Delta\rho$ values are plotted in the figure; the dilute alloy limit of $\Delta\rho/c$ was reported as 0.36×10^{-8} Ωm per atomic percent Au in Ag; data read from figure.
33	316	Linde, J.O.	1968	B		1.3-17.5	Similar to the above specimens; the dilute alloy limit of $\Delta\rho/c$ was reported as 0.32×10^{-8} Ωm per atomic percent Ag in Au.
34	287	Rudnitskii, A.A.	1946		293	0-100	Measurement temperature not stated explicitly, assumed to be 293 K; data extracted from table.
35	317	Strouhal, V. and Barus, C.	1883		273	14.8-89.1	Original paper not available; data as reported by Borelius, G., [Ann. d. Phys., 4, 77(2), 109-37, 1925]; data read from figure.
36	318	Clay, J.	1911		273	0.721-62.75	Reported compositions represent the total impurity of the sample and not necessarily the Ag content alone (for details, see data sets 66-74 of gold + silver alloys); alloys supplied by Dr. Holtsema, drawn by Heraeus to wires of 0.1 mm diam, annealed, and wound around glass cylinders; resistivities deduced from resistance measurements in the 12-170 K range and the resistivity at 273 K, calculated according to Matthiessen's observations; data extracted from table.
37	318	Clay, J.	1911		169.33	0.721-62.75	The above specimens measured at 169.33 K.
38	318	Clay, J.	1911		90.43	0.721-62.75	The above specimens measured at 90.43 K.

TABLE 55. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF GOLD–SILVER ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Ag)	Composition (weight percent), Specifications, and Remarks
39	318	Clay, J.	1911		20.24	0.721–62.75	The above specimens measured at 20.24 K.
40	319	Auer, H., Riedl, E., and Seemann, H.J.	1934		293	0–100	Spectrographic analysis showed less than 10^{-4}% Fe; Fe content primarily superficial rather than bulk and reduced to minimum by successive acid treatments; final shape of specimens cylindrical rods 4 mm in diam and 120 mm long; material initially cast in square forms 8 mm thick and then rolled to intermediate 5 mm thick stage of square cross section; rinsed with dilute hydrochloric acid, annealed at 1073 K and drawn to 4 mm; rinsed in dilute hydrochloric acid again and measured in this initial state; alloys designated as Series A; data extracted by author; from table.
41	319	Auer, H., et al.	1934		293	0–100	The above specimens annealed at 1073 K for 4 h in vacuum to remove gas content and air cooled.
42	319	Auer, H., et al.	1934		293	0–100	The above specimens remelted in vacuum, reduced to 2.5 to 3.5 mm diam and annealed several hours in vacuum before measuring.
43	319	Auer, H., et al.	1934		293	0–100	Cylindrical specimens 4 mm in diam and 100 mm long and measured in initial state; alloys designated as series B by author; date extracted from table.
44	319	Auer, H., et al.	1934		293	20.7–80.3	The above specimens measured after annealed in vacuum at 1073 K.
45	320	Bridgman, P.W.	1933		303	25–75	Compositions determined by weighing component elements; initial material prepared by Mehl, R., Superintendent of Department of Metallurgy at Naval Research Laboratory by melting weighed amounts of components in vacuum and annealing at 1193 K for 40 h; forged into bars 3 mm in diam and about 2.5 cm long and annealed again; bars lengthened by forging an additional 15%, annealed at 1173 K for 30 min and turned in jeweller's lathe to true cylinder; drawn out through steel dies, with frequent annealings in open gas flame, to final diam of 0.048 cm; final annealing at 1173 K in electric furnace, protected by quartz tubing; tabular data presentation; the average temperature coefficients of resistance at atmospheric pressure between 0 and 100 °C for the 25, 50, and 75 at.% Ag alloys were 0.001048, 0.000774, and 0.000888 ($\mu\Omega$ cm K^{-1}) respectively.
46*	362	Iyer, V.K. and Asimow, R.M.	1967		300	0–100	Spectrographic analysis showed total impurities less than 0.1% with 0.05% Si; 99.999 pure Ag and Au melted together in graphite crucible in Ar, 0.125 in ingots swaged to 0.040 in diam wire and then drawn to 0.010 in diam; measured in vacuum, values are averages of measurements on two specimens for each composition; temperature accurate to ±0.3%, resistivity to 2% with error mainly due to uncertainty in length and density; corrected for thermal expansion; data read from figure.

* Not shown in figure.

TABLE 56. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD-SILVER ALLOY SYSTEM (Composition Dependence)

[Composition, C, a/o Ag; Electrical Resistivity, ρ, 10^{-8} Ωm]

DATA SET 1* (T = 1408 K)

C	ρ
0	32.0
18.6	35.7
35.6	37.1
50.8	36.1
65.4	33.7
80.5	29.3
90.5	25.3
100	18.7

DATA SET 2 (T = 4 K)

C	ρ
0	0
10	2.83
20	5.29
30	7.20
40	8.47
50	8.98
60	8.82
70	7.65
80	5.82
90	3.32
100	0

DATA SET 3 (T = 77 K)

C	ρ
0	0.45
10	3.36
20	5.81
30	7.72
40	8.95
50	9.41
60	9.17
70	8.05
80	6.22
90	3.66
100	0.28

DATA SET 4 (T = 293.2 K)

C	ρ
0	2.23
1	2.47
4	3.25
10	4.98
20	7.30
40	10.64
60	10.75
80	7.52
90	5.03*
95	3.50
98	2.49
99	2.01
100	1.61

DATA SET 5* (T = 1373 K)

C	ρ
0	31.9
12.5	34.8
25	35.7
28	36.4
30	35.9
32	36.2
33.3	36.9
34	36.6
35	36.1
40	35.8
50	35.7
62.5	33.2
66.7	32.7
70	31.1
72	31.5
74	30.4
75.5	30.2
77	29.0
87.5	24.2
100	18.5

DATA SET 6* (T = 1473 K)

C	ρ
0	33.2
12.5	36.3
25	37.2
28	38.0
30	37.6
32	38.2
33.3	38.5
34	38.2
35	37.6
40	37.4
50	37.1
62.5	34.6
66.7	34.3
70	32.5
72	32.9
74	31.9
75.5	31.6
77	30.3
87.5	25.1
100	19.4

DATA SET 7 (T = 273.2 K)

C	ρ
0	2.27
4.9	3.98
10.7	5.52
18.7	7.58
29.7	9.80
40.1	11.0
44.9	11.2
49.1	13.9
54.6	11.0
60.3	11.0
69.8	9.71
80.0	8.00
85.5	6.80
90.3	5.13
95.0	3.41
100	1.88

DATA SET 8 (T = 373.2 K)

C	ρ
0	3.12
4.9	4.55
10.7	6.29
18.7	8.06
29.7	10.4
40.1	11.8
44.9	11.9*
49.1	13.9*
54.6	11.8
60.3	11.9
69.8	10.3
80.0	8.70
85.5	7.41
90.3	6.25
95.0	4.13
100	2.57

DATA SET 9 (T = 4.2 K)

C	ρ
0.15	0.053
0.37	0.135
0.85	0.307
1.9	0.670
2.4	0.855
4.1	1.404
7.8	2.603
21.0	6.038
73.0	7.084
90.0	3.303
94.3	1.923
94.7	1.813
97.8	0.768
98.35	0.593
98.63	0.493
99.21	0.285
99.31	0.249
99.91	0.033

DATA SET 10 (T = 273.2 K)

C	ρ
0.15	2.128
0.37	2.209
0.85	2.421
2.4	2.991
4.1	3.517
7.8	4.695
21.0	8.107
73.0	8.874
90.0	4.958
94.3	3.581
94.7	3.403
97.8	2.507
98.35	2.126
98.63	2.052
99.21	1.788
99.31	1.758
99.91	1.532

DATA SET 11 (T = 4.2 K)

C	ρ
2.0	0.584
5.0	1.401
10.0	2.801*
10.0	2.788
17.5	4.627
25.0	6.239
50.0	9.020
70.0	7.774
80.0	5.835
90.0	3.360
98.0	0.736
100	0.000*

DATA SET 12 (T = 77 K)

C	ρ
2.0	1.067
5.0	1.890
10.0	3.268
10.0	3.275*
17.5	5.111
25.0	6.745
50.0	9.407*
70.0	8.127
80.0	6.199*
90.0	3.668
98.0	1.047
100	0.270*

DATA SET 13 (T = 295 K)

C	ρ
2.0	2.836
5.0	3.672
10.0	5.120
10.0	5.113*
17.5	6.911
25.0	8.488
50.0	11.147
70.0	9.747
80.0	7.723
90.0	5.135
98.0	2.375
100	1.618*

DATA SET 14* (T = 1.6 K)

C	ρ
0.09	0.0320
0.25	0.0805
0.94	0.292

DATA SET 15 (T = 4.2 K)

C	ρ
99.00	0.359
99.50	0.185
99.75	0.094
99.90	0.039*

DATA SET 16 (T = 1.6 K)

C	ρ
0.2	0.2416
9.99	2.788*
29.98	7.076
49.90	9.009*
69.98	7.677
89.99	3.400

DATA SET 17* (T = 12.0 K)

C	ρ
0.2	0.2349
9.99	2.790
29.98	7.078
49.90	9.015
69.98	7.678
89.99	3.405

* Not shown in figure.

TABLE 56. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD-SILVER ALLOY SYSTEM (Composition Dependence) (continued)

C	ρ
DATA SET 18 (T = 81.36 K)	
0.2	0.7537
9.99	3.303
29.98	7.567
49.90	9.473
69.98	8.095
89.99	3.781
DATA SET 19 (T = 273.1 K)	
0.2	2.44
9.99	4.87
29.98	9.10
49.90	10.96
69.98	9.46
89.99	5.06
DATA SET 20 (T = 293.57 K)	
0.2	2.62
9.99	5.035
29.98	9.240
49.90	11.117
69.98	9.628
89.99	5.195
DATA SET 21 (T = 273 K)	
2.10	2.76
10.21	4.925
23.13	8.000
35.51	9.925
48.46	10.210
62.51	10.090
79.29	7.645
91.53	4.295
98.05	2.290
DATA SET 22* (T = 0 K)	
99.06	0.3470
99.65	0.1230
99.82	0.0650
99.93	0.0314

C	ρ
DATA SET 22 (cont.)* (T = 0 K)	
99.965	0.0156
99.982	0.00858
DATA SET 23* (T = 4.2 K)	
99.5	0.50
99.54	0.16
99.72	0.10
99.79	0.07
99.95	0.02
DATA SET 24 (T = 77.3 K)	
98.5	0.81
99.54	0.44
99.72	0.38*
99.79	0.35
99.95	0.29*
DATA SET 25 (T = 273 K)	
98.5	1.99
99.54	1.62
99.72	1.54*
99.79	1.52*
99.95	1.48
DATA SET 26 (T = 295 K)	
98.5	2.13*
99.54	1.76
99.72	1.67*
99.79	1.65
99.95	1.61*
DATA SET 27 (T = 291 K)	
96.98	2.703
97.98	2.355*
99.09	1.954

C	ρ
DATA SET 28 (T = 173 K)	
96.98	1.980
97.98	1.637
99.09	1.235
DATA SET 29 (T = 93 K)	
96.98	1.484
97.98	1.138
99.09	0.740
DATA SET 30 (T = 273 K)	
0	2.04
3.59	3.24
8.77	4.39
16.9	7.19
24.4	7.81
31.3	8.20
37.8	10.0
54.9	10.5
64.6	10.1
73.3	9.01
81.0	7.81
88.0	5.59
91.2	4.59
94.3	3.62*
97.2	2.48
99.2	1.87
DATA SET 31 (T = 293 K)	
0.00	2.43
13.52	8.01
42.06	10.98
52.24	10.97
64.94	9.89
76.08	8.56
89.85	5.03
95.41	3.26
100.00	1.66

C	ρ
DATA SET 32	
83.0	5.34
91.9	2.75
97.0	1.78
97.5	0.900
99.0	0.341*
DATA SET 33	
1.3	0.398
2.8	0.879
8.1	2.38
17.5	4.67
DATA SET 34 (T = 293 K)	
0.0	3.05
9.7	5.80
19.7	8.24
29.6	10.05
39.6	11.13
49.8	11.60
59.6	11.31
69.7	10.16
79.9	8.42
89.8	5.71
99.8	2.17
DATA SET 35 (T = 273 K)	
14.8	3.50
29.6	7.40
36.4	8.70
54.9	11.4
67.4	10.3
69.6	10.6
79.5	8.70
89.1	5.65
DATA SET 36 (T = 273 K)	
0.721	2.371
0.866	2.416*
0.953	2.444*
1.574	2.637
2.531	2.930

C	ρ
DATA SET 36 (cont.) (T = 273 K)	
31.39	9.197
62.75	9.937
DATA SET 37 (T = 169.33 K)	
0.721	1.530
0.866	1.570*
0.953	1.596*
1.574	1.806
2.531	2.093
31.39	8.397
62.75	9.137
DATA SET 38 (T = 90.43 K)	
0.721	0.881
0.866	0.916*
0.953	0.940*
1.574	1.161
2.531	1.443
31.39	7.756
62.75	8.642
DATA SET 39 (T = 20.24 K)	
0.721	0.307*
0.866	0.359
0.953	0.380*
1.574	0.606
2.531	0.876
31.39	7.211
62.75	8.168
DATA SET 40 (T = 293 K)	
0	2.25*
20.10	7.50
39.60	10.42
60.22	10.60
79.97	7.62
100	1.63*

C	ρ
DATA SET 41 (T = 293 K)	
0	2.27*
20.10	7.44
39.60	10.44*
60.22	10.62*
79.97	7.72*
100	1.59*
DATA SET 42 (T = 293 K)	
0	2.34
20.10	7.45*
39.60	10.40*
60.22	10.66
79.97	7.68*
100	1.60*
DATA SET 43 (T = 293 K)	
0	2.22*
20.7	7.66
40.4	10.50
59.9	10.61
80.3	7.54
100	1.72
DATA SET 44 (T = 293 K)	
20.7	7.57
40.4	10.45
59.9	10.66
80.3	7.61
DATA SET 45 (T = 303 K)	
25	8.65
50	10.9
75	8.64
DATA SET 46* (T = 300 K)	
0.0	2.35
5.0	3.79

* Not shown in figure.

TABLE 56. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF GOLD–SILVER ALLOY SYSTEM (Composition Dependence) (continued)

C	ρ
DATA SET 46 (cont.)* (T = 300 K)	
10.0	5.11
30.0	9.54
50.0	11.26
70.0	9.76
90.0	5.09
95.0	3.43
100.0	1.69

* Not shown in figure.

3.9. Iron-Nickel Alloy System

The electrical resistivity of the iron-nickel alloy system has received a considerable amount of attention, no doubt due in large measure to both elements being present in a large number of technologically important alloys. There are 45 data-source references available in the literature on the electrical resistivity of Fe-Ni alloys. From these references, 198 sets of experimental data were obtained spanning a temperature range 0.4 to 1995 K. These experimental data sets are listed in tables 58, 60, and 62 which provide information on specimen characterization and measurement conditions, tabulated in tables 59, 61, and 63, and shown partially in figures 47, 48, and 50.

The iron-nickel alloy system does not form a continuous series of solid solutions at moderate and low temperatures (below 1183 K). The maximum solid solubility of nickel in iron is 6.81 wt.% (6.5 at.%) at 618 K and the solubility decreases at higher and lower temperatures [321]. For nickel-rich alloys the solubility of iron in nickel is uncertain due to the formation of $FeNi_3$ ordered structure; it may be below 3 wt.% around room temperature. In addition, there is a martensitic transformation from metastable austenite in alloys containing up to 30 wt.% Ni resulting in a metastable α_2 phase. The phase diagram is further complicated by magnetic transitions: at about 1040 K in the α phase, at about 673 K in the $\alpha + \gamma$ equilibrium phase mixture, and on a curve reaching a maximum of about 885 K at about 66 wt.% Ni in the γ phase [264]. Finally, there is an order-disorder transformation due to the formation of $FeNi_3$ covering a wide range of composition, from perhaps 50 to 85 wt.% Ni, which has a maximum transition temperature of about 776 K.

Regarding the metastable states in the iron-rich region, early work identified the transformation of metastable austenite as being of the diffusionless, martensitic type [322]. Later, effects of strain and grain size upon martensite formation were studied from changes in the electrical resistivity [323,324]. The results indicate that the transformation is essentially independent of heating/cooling rate, the transformation may occur over an interval of temperatures spanning perhaps 100 degrees for a 30% Ni alloy, and the amount of martensite formed upon cooling depends upon specimen history.

The electrical resistivity of dilute alloys with either iron or nickel as base metal has been measured during investigations of the deviations from

the Matthiesson's rule. At the lowest temperatures the deviations follow a roughly T^2 behavior attributed to spin-mixing as reported by Fert and Campbell [325] (Fe + Ni data set 93) for 1% or 2% Ni in Fe and by Farrell and Greig [326] (Ni + Fe data sets 3-5) for up to 5% Fe in Ni. Further, the variation with composition is quite weak at these temperatures. Near room temperature the rapidly rising deviations have leveled off as observed by Farrell and Greig [326], Schwerer and Conroy [327] (Ni + Fe data sets 47-51), and Schwerer and Cuddy [328] (Fe + Ni data set 94). Above 300 K Schwerer and Cuddy [329] (Fe + Ni data sets 95, 96 and Ni + Fe data sets 64, 65) find evidence for spin-disorder resistivity in the generally decreasing temperature dependence of the deviations for both 1% Ni in Fe and 1% Fe in Ni at temperatures up to the Curie point.

Electrical resistivity of alloys with compositions in the ≤30% Ni region is well documented. The extensive measurements of Shirakawa [330] (Fe + Ni data sets 65-76) from 78 to 1123 K map out the temperature hysteresis loops for alloys with compositions between 4 and 30% Ni. It is unfortunate that the resistivity data reported on the lower Ni content specimens are atypically small in value, increasingly so at elevated temperatures; this is perhaps the result of problems inherent with a two-probe measurement technique. These findings were confirmed by the work of Ascher [331] (Fe + Ni data sets 90, 91) in which a 30% Ni specimen had been chilled in liquid air prior to measurement. The specimen was subsequently subjected to a complete temperature cycle with the resulting electrical resistivity in both martensitic and austenitic states being in close agreement with that of Shirakawa [330]. The change in electrical resistivity upon transforming the austenite to martensite is quite striking for this composition, amounting to a reduction of about 60%. A number of alloy compositions had previously been measured by Ingersoll [332] (Fe + Ni data sets 1-8) at these temperatures, but with only heating curves reported. In retrospect it may be noted that these smoothed data apparently do show the onset of the inverse transformation at higher temperatures. Recent work by Reed et al. [333] (Fe + Ni data sets 36-39) on an alloy with 29% Ni show the effects of a low-temperature anneal upon the electrical resistivity. The findings include the following: annealing of point defects affects only the residual resistivity such that the observed $3.1 \times 10^{-8}\ \Omega\,m$ residual resistivity recovery corresponds to an estimated 0.5 at.% in point defect concentration, the reduction in electri al resistivity which accompanies the martensitic

transformation amounts to an average of 0.46 x 10^{-8} Ω m/percent martensite at 293 K, and the effects of dislocations upon electrical resistivity is negligible at room temperature, with estimates being down at the 0.1 x 10^{-8} Ω m level. Also are the findings of Livingston and Mukherjee [334] (Fe + Ni data set 42) on a slow-cooled specimen with 29.7 at.% Ni which show a very rapid onset to the decrease in resistivity at the transformation temperature.

The Invar composition range of about 35% to 50% Ni has received recent attention. The residual resistivity is found to increase sharply with increasing iron content. An explanation in terms of a weak ferromagnet model was suggested both by Armstrong and Fletcher [335] and by Gautier and Loegel [336]. Further, the temperature dependent resistivity is found to increase with temperature as T^n, where n is reported as n = 2 below 60 K [336] and n = 1.8 to 2.0 up to 120 K [335]. Generally, the residual resistivity data from [335] (Fe-Ni data set 34) along with those of Mikhailova [337] (Fe + Ni data set 48) and Clark et al. [103] (Fe + Ni data sets 31, 32, and Ni + Fe data set 32) are for commercial grade materials. Consequently, these data lie somewhat above those [336] (Fe + Ni data sets 50-56), of Larikov et al. [338] (Fe-Ni data set 27), and of Kondorskii and Sedov [339] (Fe-Ni data set 26). Near room temperature are the data of Jellinghaus and Andres [340] (Fe-Ni data set 30), Kalinin et al. [341] (Fe-Ni data set 25), and Window [342] (Fe-Ni data set 29), all of which are in reasonably good agreement. At higher temperatures are the data of Larikov et al. [338] (Fe + Ni data sets 80-83 and Ni + Fe data set 61) up to 1300 K and of Somura [343] (Fe + Ni data sets 84-89) up to about 800 K. Both of them reported a concentration dependence that varies rapidly, but diminishes toward the highest temperatures, and perhaps even disappears above 700 K [343]. Also in this connection are the weakly concentration-dependent data reported by Window [342] (Fe-Ni data set 28) at 873 K. If, as has been suggested, alloys in the Invar range are describable in terms of a mixed phase model (see, for instance ref. [344]), then specimen thermal history becomes very important. For instance, the cooling data reported by Larikov et al. [338] deviate toward slightly smaller resistivity values, but only below the Curie temperature. This may indicate that some phase segregation is taking place.

In the nickel-rich portion of the Fe-Ni system, the formation of ordering associated with $FeNi_3$ has been intensively studied. Basically two techniques

have been reported to achieve the order. Following the initial high-temperature annealing a sequence of anneals below the critical temperature may be carried out. Or, a constant cooling rate may be applied. The first method was used in the early work of Källback [345] who reported electrical resistivity of the disordered (quenched) state (Ni + Fe data set 29) and also of states with partial, but undetermined amounts of order (Ni + Fe data set 28). Recently Moore et al. [346] (Ni + Fe data sets 39-42) subjected an alloy to a series of extended anneals designed to achieve essentially complete ordering. The electrical resistivity was reduced some 35% for temperatures between 4.2 K and 400 K by this procedure. The second method of producing order was reported by Wakelin and Yates [347] (Ni + Fe data sets 9-27) who applied cooling rates from 100 deg hr^{-1} to 0.1 deg hr^{-1} on alloys containing 50%-80% Ni. The essentially linear nature of the cooling curves at the slower cooling rates suggested that the fully ordered state was achieved. However, the cooling curves for the slower rates were relatively displaced, perhaps indicating that an extra resistivity mechanism was present. This was tentatively identified with dislocations being frozen in during the rapid cooldowns. Overall, this method resulted in alloy specimens having varying degrees of order. Consequently, some ambiguities arise when making comparisons of the electrical resistivity data on these alloy specimens with other data.

Data which fall between the two preceding composition ranges are those reported by Szentirmay [348] (Ni + Fe data sets 62, 63) on alloys with 58% and 65% Ni. The data are for quenched alloys at temperatures between 150 K and 350 K. The 58% Ni specimen was later subjected to an anneal following which the electrical resistivity was shown to be reduced by some 2%-5%.

The electrical resistivity of the molten alloys shows a linear temperature dependence as reported by Ono and Yagi [349] (Fe + Ni data sets 40, 41 and Ni + Fe data sets 34-36), by Baum et al. [350] (Fe + Ni data sets 57-64, Ni + Fe data sets 52-55, and Fe-Ni data set 24), and by Epin et al. [351] (Fe-Ni data set 33). The slope values reported in ref. [349,351] agree rather well for the nickel-rich compositions while those from ref. [350] are lower by a factor of ten. The ratio of resistivities, liquid to solid, for compositions throughout the alloy system was also reported in ref. [351]. An alloy with 75% Ni was reported by Ono and Yagi [349] to show an anomalously low resistivity. This was attributed to possible $FeNi_3$ clusters. Temperature hysteresis was

reported by Baum et al. [350] upon cycling through the melting range. This may be an indication of the tendency for structures in the Fe-Ni system to be retained into the melting range as suggested by Filippov and Krestonikov [352].

Much early work on the electrical resistivity of the iron-nickel system was devoted to mapping out the composition dependence. This information, usually obtained at or near room temperature, helped to form initial insights into the inner workings of this sytem. The early efforts of Burgess and Aston [353] (Fe-Ni data set 10) directed toward technical application were followed by the work of Honda [354] (Fe-Ni data sets 7, 8) showing the effects of cold-chilling on alloys having ≤30% Ni, by the combined composition and temperature dependence measurements of Ingersoll [332] (Fe-Ni data sets 14-22), and by the careful pressure dependence measurements of Bridgman [355] (Fe-Ni data set 12).

Each of the experimental areas discussed above formed the basis for a set of recommendations. These were subsequently merged smoothly together to form the recommendations for the entire Fe-Ni system.

Recommendations for the residual resistivity were based upon a number of low temperature data sets which generally included a value at 4.2 K. These are the data of Fert and Campbell [325], Schwerer and Cuddy [329], and Reed et al. [333] for low nickel compositions. Also based upon were the temperature-dependent data of Bäcklund [356] (Fe + Ni data sets 13, 14) and Soffer et al. [357] (Fe + Ni data sets 20-24), from which ρ_0 was extracted. At higher nickel compositions the recommendations were based on the data of Cadeville and Loegel [358] (Fe-Ni data set 9), Larikov et al. [338], and Kondorskii and Sedov [339] for 35-60% Ni, of Van Elst and Gorter [220] (Ni + Fe data set 6) and Moore et al. [346] (disordered state only) for 75% Ni, of Berger and Rivier [359] (Ni + Fe data set 2) for 85% Ni, and of Farrell and Greig [326], Schwerer and Conroy [327], Fert and Campbell [325], and Schwerer and Cuddy [329] for ≥ 95% Ni.

At low temperatures, the temperature-dependent resistivity follows a T^2 dependence. The scattering strength is quite strong in the invar region, in which the recommendations follow the data of Gautier and Loegel [336], and diminishes with increasing base metal compositions, for which the recommendations follow the data of Soffer et al. [357], Fert and Campbell [325], Schwerer and Cuddy [328], Farrell and Greig [326], and Schwerer and Conroy [327].

At higher temperatures, a cross-correlation involving both temperature and composition was applied. The data used for this were those of Schwerer and Cuddy [328,329], Soffer et al. [357], Bäcklund [356], Reed et al. [333], Livingston and Mukherjee [334], Ascher [331], Shirakawa [330], Ingersoll [332], Larikov et al. [338], Szentirmay [348], Moore et al. [346], Farrell and Greig [326], and of Schwerer and Conroy [327]. Curie temperatures were taken from Hansen [264].

For the martensitic and austenitic metastable states, recommendations are given for compositions between 3 and 30% Ni. The transformation temperatures are the median, 50% transformation completion, values from Hansen [264]. Values applicable to a 30% Ni composition follow the data of Reed et al. [333] and Livingston and Mukherjee [334] up to 300 K. The temperature hysteresis loops for all compositions are based upon the data of Ascher [331] and of Shirakawa [330].

Recommendations at high temperatures include values for the liquid state. Solidus and liquidus temperatures are taken from Hansen [264]. Values for the solid state are based upon the data of Baum et al. [350], and for the step-up resistivity increase across the melting range upon the ρ_ℓ/ρ_s data from Epin et al. [351]. The linear temperature dependence of the electrical resistivity in the molten region follows the slope values reported by Epin et al. [351], and for nickel-rich compositions also follows the slope values reported by Ono and Yagi [349].

It may be worthwhile to point out that the data from ref. [349-351] were measured with a rotating field method. Since the electrical resistivity in this case is proportional to specimen volume (see for instance ref. [349]), a significant thermal expansion correction arises, amounting to 7-8% for pure nickel or iron at the melting point. Therefore, inasmuch as ref. [349] reports expansion corrections having been applied to the data, it is thought that actually all three references, [349-351], are reporting corrected data. As a result, the recommended values for alloys below 1300 K are not corrected for thermal expansion, while those at higher temperatures, up to and beyond the melting range, do in fact include the corrections.

The resulting recommended electrical resistivity values for Fe, Ni, and for 25 Fe-Ni binary alloys are presented in table 57 and shown in figures 43-46, and 49. The recommended values for Fe and for Ni are for well-annealed

high-purity specimens, but those values for temperatures below about 100 K are applicable only to Fe and Ni having residual electrical resistivities as given at 1 K in table 57. The alloys for which the recommended values are generated are those having the stated compositions and being in the appropriate metallurgical state. The latter includes the fully martensitic or austenitic metastable states for 3% to 30% Ni and the completely disordered state for other compositions. The recommended values cover a full range of temperature from 1 K to 2000 K for both solid and molten states. The estimated uncertainties in the values for the various alloys and for different temperature ranges are explicitly stated in a footnote to table 57. Some of the values in table 57 are indicated as provisional because their uncertainties are greater than ±5%.

TABLE 57. RECOMMENDED ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM†

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Fe: 100.00% (100.00 At.%) Ni: 0.00% (0.00 At.%)		Fe: 99.50% (99.52 At.%) Ni: 0.50% (0.48 At.%)		Fe: 99.00% (99.05 At.%) Ni: 1.00% (0.95 At.%)		Fe: 97.00% (97.14 At.%) Ni: 3.00% (2.86 At.%)			Fe: 95.00% (95.23 At.%) Ni: 5.00% (4.77 At.%)			Fe: 90.00% (90.44 At.%) Ni: 10.00% (9.56 At.%)		
T	ρ	T	ρ	T	ρ	T	ρ_M	ρ_A	T	ρ_M	ρ_A	T	ρ_M	ρ_A
1	0.0225	1	0.95	1	1.90	1	5.60*		1	8.15*‡		1	12.4*‡	
4	0.0227	4	0.95	4	1.90	4	5.60*		4	8.15*‡		4	12.4*‡	
7	0.0231	7	0.95	7	1.90	7	5.60*		7	8.16*‡		7	12.4*‡	
10	0.0238	10	0.95	10	1.91	10	5.61*		10	8.16*‡		10	12.4*‡	
15	0.0257	15	0.96	15	1.91	15	5.62*		15	8.18*‡		15	12.4*‡	
20	0.0287	20	0.96	20	1.92	20	5.64*		20	8.20*‡		20	12.4*‡	
30	0.0421	30	0.98	30	1.95	30	5.68*		30	8.27*‡		30	12.5*‡	
40	0.0756	40	1.03	40	2.00	40	5.76*		40	8.36*‡		40	12.6*‡	
50	0.148	50	1.11	50	2.09	50	5.87*		50	8.49*‡		50	12.8*‡	
60	0.271	60	1.23	60	2.23	60	6.04*		60	8.66*‡		60	13.0*‡	
70	0.452	70	1.42	70	2.42	70	6.26*		70	8.91*‡		70	13.3*‡	
80	0.693	80	1.67	80	2.67	80	6.54*		80	9.22‡		80	13.7‡	
90	0.967	90	1.96	90	2.97	90	6.89		90	9.60‡		90	14.1‡	
100	1.28	100	2.30	100	3.32	100	7.29		100	10.0		100	14.5	
150	3.15	150	4.18	150	5.15	150	9.34		150	12.1		150	17.0	
200	5.20	200	6.24	200	7.36	200	11.7		200	14.7		200	19.8	
250	7.44	250	8.56	250	9.70	250	14.1		250	17.3		250	22.7	
273	8.57	273	9.72	273	10.9	273	15.4		273	18.7		273	24.2	
293	9.61	293	10.8	293	12.0	293	16.5		293	19.9		293	25.5	
300	9.98	300	11.1	300	12.4	300	16.9		300	20.2		300	25.9	
400	16.1	400	17.4	400	18.7	400	23.3		400	26.8		400	33.2	
500	23.7	500	25.0	500	26.3	500	31.0		500	34.6		500	41.6	
600	32.9	600	34.2	600	35.4	600	40.1		600	43.8		600	51.5	
700	44.0	700	45.3	700	46.4	700	51.2		700	55.2		700	63.1	
800	57.1	800	58.3	800	59.6	800	64.7		800	68.5		770	72.5	95.6
1000	90.8	900	73.7	900	75.1	900	80.5		900	84.7		800	77.1	97.3
1043	101.1	1000	91.9	1000	93.1	995	97.4*	103.9*	925	88.9	102.2	900	92.6	102.9
1185	111.9(α)	1040	101.3	1037	101.6	1000	98.3*	104.4*	1000	102.3	105.5	965	104.4	106.2
1185	111.0(γ)	1100	107.4	1100	107.8	1075	108.0*	108.0*	1035	107.4	107.4	1000		107.8
1400	117.9	1200	111.8*	1200	112.0	1200		113.2	1200		114.1	1200		115.9*
1667	124.4(γ)	1400	118.2*	1400	118.6	1400		119.9	1400		120.8	1400		122.7*
1667	124.6(δ)	1600	123.4*	1600	123.8	1600		125.2	1600		126.3	1600		126.6*
1811	126.2(s)	1808	128.3*(s)	1803	128.4*(s)	1791		129.5*(s)	1782		130.7(s)	1762		132.6*(s)
1811	135.2(ℓ)	1810	135.4*(ℓ)	1808	135.6*(ℓ)	1800		136.4*(ℓ)	1793		137.4(ℓ)	1777		139.0*(ℓ)
2000	138.2	2000	138.4*	2000	138.6*	2000		139.7*	2000		140.6	2000		142.4*

† Uncertainties in the electrical resistivity values are as follows:

100.00 Fe - 0.00 Ni: ±5% from 50 K to 100 K, ±3% above 100 K to 200 K, ±2% above 200 K to 1811 K, and ±5% above 1811 K.
99.50 Fe - 0.50 Ni: ±5% below 100 K, ±3% from 100 K to 200 K, ±2% above 200 K to 1808 K, and ±5% above 1808 K.
99.00 Fe - 1.00 Ni: ±5% below 100 K, ±3% from 100 K to 200 K, ±2% above 200 K to 1803 K, and ±5% above 1803 K.
97.00 Fe - 3.00 Ni: ±5% below 1075 K (martensite), ±3% from 995 K to 1791 K (austenite), and ±5% above 1791 K.
95.00 Fe - 5.00 Ni: ±7% below 100 K, ±5% from 100 K to 1035 K (martensite), ±3% from 925 K to 1782 K (austenite), and ±5% above 1782 K.
90.00 Fe - 10.00 Ni: ±7% below 100 K, ±5% from 100 K to 965 K (martensite), ±3% from 770 K to 1762 K (austenite), and ±5% above 1762 K.

ρ_M, ρ_A Electrical resistivity for martensite, austenite respectively.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 57. RECOMMENDED ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Fe: 85.00% (85.63 At.%) Ni: 15.00% (14.37 At.%)			Fe: 80.00% (80.79 At.%) Ni: 20.00% (19.21 At.%)			Fe: 75.00% (75.93 At.%) Ni: 25.00% (24.07 At.%)			Fe: 70.00% (71.04 At.%) Ni: 30.00% (28.96 At.%)			Fe: 65.00% (66.13 At.%) Ni: 35.00% (33.87 At.%)		Fe: 60.00% (61.19 At.%) Ni: 40.00% (38.81 At.%)	
T	ρ_M	ρ_A	T	ρ_M	ρ_A	T	ρ_M	ρ_A	T	ρ_M	ρ_A	T	ρ	T	ρ
1	15.1*‡		1	16.8*‡		1	17.8*		1	18.2*		1	47.9‡	1	22.9*‡
4	15.1*‡		4	16.8*‡		4	17.8		4	18.2		4	47.9‡	4	22.9‡
7	15.1*‡		7	16.8*‡		7	17.8		7	18.2		7	47.9‡	7	22.9‡
10	15.1*‡		10	16.8*‡		10	17.8		10	18.2		10	48.0‡	10	23.0‡
15	15.1*‡		15	16.8*‡		15	17.8		15	18.3		15	48.1‡	15	23.0‡
20	15.1*‡		20	16.9*‡		20	17.9		20	18.3		20	48.2‡	20	23.2‡
30	15.2*‡		30	17.0*‡		30	18.0		30	18.4		30	48.6‡	30	23.5‡
40	15.4*‡		40	17.1*‡		40	18.2		40	18.6		40	49.1‡	40	23.9‡
50	15.6*‡		50	17.3*‡		50	18.4		50	18.9		50	49.7‡	50	24.5‡
60	15.8*‡		60	17.6*‡		60	18.7		60	19.2		60	50.5‡	60	25.2‡
70	16.2*‡		70	18.0*‡		70	19.1		70	19.6		70	51.4‡	70	25.9‡
80	16.6‡		80	18.4‡		80	19.5		80	20.0		80	52.5‡	80	26.7‡
90	17.0‡		90	18.9‡		90	19.9		90	20.4		90	53.5‡	90	27.7‡
100	17.5		100	19.3		100	20.4		100	20.9		100	54.7‡	100	28.6‡
150	20.0		150	22.1		150	23.3		150	23.7		150	61.7‡	150	34.5‡
200	23.0		200	25.2		200	26.4		200	27.0		200	68.9‡	200	41.8
250	26.2		250	28.5		250	29.9		250	30.6	76.8	250	76.2‡	250	50.0
273	27.8		273	30.1		273	31.6		273	32.3	78.9	273	79.4‡	273	53.8
293	29.2		293	31.6		293	33.0		293	33.9	80.9	293	82.0‡	293	57.1
300	29.7		300	32.2		300	33.5		300	34.4	81.4	300	83.0	300	58.2
400	37.3		400	40.0		395	41.1	85.4	400	42.4	90.5	400	94.3	400	73.9
500	46.2		500	49.0		400	41.5	85.9	500	51.8	97.5	482	101.6	500	88.5
600	56.7		535	52.6	90.6	500	50.8	93.2	600	62.8	102.7	500	102.4	600	101.1
635	60.9	92.0	600	59.8	94.6	600	61.7	98.9	700	75.2	106.7	600	106.4	604	101.4
700	68.6	95.8	700	72.0	99.8	700	73.9	103.4	740	80.4	108.1	700	109.9	700	105.6
800	83.0	100.9	800	86.2	104.2	800	87.9	107.1	800		110.1	800	113.2	800	109.1
900	97.0	105.6	875	98.2	107.2	810	89.4	107.4	900		113.5	900	116.2	900	112.3
920	102.9	106.4	900		108.1	900		110.4	1000		116.5	1000	119.1	1000	115.5
1000		109.7	1000		111.5	1000		113.7	1100		119.4	1100	121.8	1100	118.3
1200		116.9*	1200		118.3*	1200		119.9*	1200		122.1*	1200	124.3	1200	121.1
1400		123.5*	1400		124.7*	1400		125.7*	1400		127.1*	1400	128.5*	1400	126.0*
1600		129.7*	1600		130.5*	1600		131.0*	1600		131.5	1600	132.0*	1600	130.2*
1748		133.8*(s)	1737		134.2*(s)	1728		134.2*(s)	1720		134.0(s)	1715	133.7*(s)	1710	132.4*(s)
1763		140.1 (ℓ)	1751		140.6 (ℓ)	1741		140.8*(ℓ)	1732		141.0(ℓ)	1724	141.3*(ℓ)	1718	140.6 (ℓ)
2000		143.7	2000		144.3	2000		144.6*	2000		144.9	2000	145.0*	2000	144.9

† Uncertainties in the electrical resistivity are as follows:

85.00 Fe - 15.00 Ni: ±7% below 100 K, ±5% from 100 K to 920 K (martensite), ±3% from 635 K to 1748 K (austenite), and ±5% above 1748 K.
80.00 Fe - 20.00 Ni: ±7% below 100 K, ±5% from 100 K to 875 K (martensite), ±3% from 535 K to 1737 K (austenite), and ±5% above 1737 K.
75.00 Fe - 25.00 Ni: ±5% below 810 K (martensite), ±3% from 395 K to 1728 K (austenite), and ±5% above 1728 K.
70.00 Fe - 30.00 Ni: ±3% below 740 K (martensite), ±3% from 250 K to 1720 K (austenite), and ±5% above 1720 K.
65.00 Fe - 35.00 Ni: ±15% below 150 K, ±10% above 150 K to 300 K, and ±5% above 300 K.
60.00 Fe - 40.00 Ni: ±10% below 200 K, ±5% from 200 K to 604 K, ±3% above 600 K to 1710 K, and ±5% above 1710 K.

ρ_M, ρ_A Electrical resistivity for martensite, austenite respectively.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 57. RECOMMENDED ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Fe: 55.00% (56.23 At.%) Ni: 45.00% (43.77 At.%)		Fe: 50.00% (51.25 At.%) Ni: 50.00% (48.75 At.%)		Fe: 45.00% (46.24 At.%) Ni: 55.00% (53.76 At.%)		Fe: 40.00% (41.21 At.%) Ni: 60.00% (58.79 At.%)		Fe: 35.00% (36.15 At.%) Ni: 65.00% (63.85 At.%)		Fe: 30.00% (31.06 At.%) Ni: 70.00% (68.94 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	13.1*‡	1	8.93*‡	1	7.00*‡	1	5.74*‡	1	4.93*‡	1	4.46*
4	13.1‡	4	8.94‡	4	7.00‡	4	5.74‡	4	4.93*‡	4	4.46*
7	13.1‡	7	8.95‡	7	7.01‡	7	5.75‡	7	4.94*‡	7	4.47*
10	13.1‡	10	8.96‡	10	7.03‡	10	5.76‡	10	4.95*‡	10	4.47*
15	13.2‡	15	9.00‡	15	7.06‡	15	5.78‡	15	4.97*‡	15	4.49*
20	13.3‡	20	9.06‡	20	7.10‡	20	5.82‡	20	4.99*‡	20	4.52*
30	13.5‡	30	9.23‡	30	7.23‡	30	5.91‡	30	5.07*‡	30	4.59*
40	13.9‡	40	9.46‡	40	7.40‡	40	6.05‡	40	5.19*‡	40	4.69*
50	14.3‡	50	9.76‡	50	7.63‡	50	6.22‡	50	5.34*‡	50	4.83*
60	14.8‡	60	10.1‡	60	7.90‡	60	6.43‡	60	5.52*‡	60	5.00*
70	15.4‡	70	10.6‡	70	8.25*‡	70	6.69‡	70	5.73*‡	70	5.20*
80	16.1‡	80	11.0‡	80	8.65*‡	80	6.99‡	80	5.98*‡	80	5.43
90	16.8‡	90	11.6‡	90	9.11*‡	90	7.35‡	90	6.28*‡	90	5.69
100	17.6‡	100	12.3‡	100	9.63*‡	100	7.73‡	100	6.55*‡	100	5.97
150	22.1‡	150	16.2‡	150	12.5*‡	150	10.2‡	150	8.49*‡	150	7.71
200	27.6‡	200	20.8‡	200	16.3*‡	200	13.3‡	200	11.3‡	200	10.2
250	33.7‡	250	25.9‡	250	21.0*‡	250	17.4‡	250	14.9‡	250	13.5
273	36.6‡	273	28.4‡	273	23.4*‡	273	19.6‡	273	17.0‡	273	15.3
293	39.2‡	293	30.6‡	293	25.6*‡	293	21.6‡	293	18.8‡	293	17.1
300	40.2	300	31.4	300	26.4*	300	22.5	300	19.6	300	17.7
400	53.9	400	43.7	400	38.3*	400	34.0	400	30.4*	400	27.4
500	66.9	500	57.5	500	51.4*	500	46.6	500	42.3*	500	38.5
600	84.7	600	72.6	600	65.4*	600	60.2	600	55.6*	600	50.7
700	101.0	700	88.4	700	80.2*	700	74.7	700	69.6*	700	64.1
703	101.2	782	101.0	800	95.9*	800	90.1	800	84.7*	800	79.1
800	104.7	800	101.8	833	100.8*	859	100.0	871	96.2*	874	91.2
900	108.1	900	105.8	900	103.9*	900	102.0	900	98.1*	900	92.5
1000	111.3	1000	109.2	1000	107.6*	1000	105.6	1000	102.1*	1000	96.7
1100	114.3	1100	112.3	1100	110.9*	1100	109.0	1100	105.9*	1100	100.8
1200	117.2	1200	115.4	1200	114.1*	1200	112.3*	1200	109.5*	1200	104.7*
1400	122.7*	1400	121.1*	1400	120.1*	1400	118.7*	1400	116.4*	1400	112.5*
1600	127.6	1600	126.3*	1600	125.7*	1600	124.9*	1600	123.0	1600	120.1*
1706	130.0(s)	1704	128.7*(s)	1703	128.4*(s)	1702	127.9*(s)	1702	126.4(s)	1702	123.6*(s)
1713	138.8(l)	1708	138.4*(l)	1705	138.9*‡(l)	1703	139.7‡(l)	1703	139.5‡(l)	1704	138.7*‡(l)
2000	144.7	2000	144.5*	2000	144.2*‡	2000	143.8‡	2000	143.3‡	2000	142.3*‡

† Uncertainties in the electrical resistivity are as follows:

55.00 Fe - 45.00 Ni: ±7% below 300 K, ±5% from 300 K to 703 K, ±3% above 703 K to 1706 K, and ±5% above 1706 K.
50.00 Fe - 50.00 Ni: ±7% below 300 K, ±5% from 300 K to 782 K, ±3% above 782 K to 1704 K, and ±5% above 1704 K.
45.00 Fe - 55.00 Ni: ±7% below 300 K, ±5% from 300 K to 833 K, ±3% above 833 K to 1703 K, and ±10% above 1703 K.
40.00 Fe - 60.00 Ni: ±7% below 300 K, ±5% from 300 K to 859 K, ±3% above 859 K to 1702 K, and ±10% above 1702 K.
35.00 Fe - 65.00 Ni: ±7% below 300 K, ±5% from 300 K to 871 K, ±3% above 871 K to 1702 K, and ±10% above 1702 K.
30.00 Fe - 70.00 Ni: ±5% below 1702 K and ±10% above.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 57. RECOMMENDED ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Fe: 25.00% (25.95 At.%) Ni: 75.00% (74.05 At.%)		Fe: 20.00% (20.81 At.%) Ni: 80.00% (79.19 At.%)		Fe: 15.00% (15.65 At.%) Ni: 85.00% (84.35 At.%)		Fe: 10.00% (10.46 At.%) Ni: 90.00% (89.54 At.%)		Fe: 5.00% (5.24 At.%) Ni: 95.00% (94.76 At.%)		Fe: 3.00% (3.15 At.%) Ni: 97.00% (96.85 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	4.26*	1	4.08*	1	3.71*	1	2.95*	1	1.73	1	1.10
4	4.26	4	4.08	4	3.71*	4	2.95*	4	1.73	4	1.10
7	4.27	7	4.09	7	3.72*	7	2.96*	7	1.74	7	1.11
10	4.27	10	4.09	10	3.72*	10	2.96*	10	1.74	10	1.11
15	4.29	15	4.11	15	3.74*	15	2.98*	15	1.76	15	1.13
20	4.31	20	4.13	20	3.76*	20	3.00*	20	1.78	20	1.15
30	4.39	30	4.20	30	3.83*	30	3.06*	30	1.84	30	1.21
40	4.49	40	4.29	40	3.92*	40	3.15*	40	1.94	40	1.30
50	4.61	50	4.42	50	4.03*	50	3.27*	50	2.06	50	1.44
60	4.77	60	4.56	60	4.17*	60	3.40*	60	2.27	60	1.61
70	4.94	70	4.73	70	4.33*	70	3.56*	70	2.50	70	1.82
80	5.14	80	4.92	80	4.52	80	3.74	80	2.76	80	2.05
90	5.37	90	5.14	90	4.64	90	3.95	90	3.04	90	2.31
100	5.62	100	5.39	100	4.97	100	4.20	100	3.34	100	2.59
150	7.30	150	7.05	150	6.59	150	5.79	150	4.93	150	4.09
200	9.71	200	9.27	200	8.64	200	7.77	200	6.66	200	5.78
250	12.8	250	12.1	250	11.2	250	10.3	250	8.65	250	7.64
273	14.3	273	13.6	273	12.6	273	11.4	273	9.66	273	8.53
293	15.9	293	14.9	293	13.8	293	12.5	293	10.6	293	9.32
300	16.4	300	15.4	300	14.2	300	12.9	300	10.9	300	9.59
400	25.1	400	23.1	400	21.1	400	18.9	400	16.1*	400	14.6*
500	35.1*	500	32.1	500	29.1	500	26.3	500	22.9*	500	20.9*
600	46.4*	600	42.3	600	38.6	600	35.4	600	31.6*	600	29.6*
700	59.0	700	54.3	700	50.5	700	47.1	679	40.6*‡	656	35.8*‡
800	73.2	800	68.7	786	63.6	733	51.7‡	700	41.8*‡	700	38.1*‡
865	83.4	833	74.1	800	64.5	800	55.1‡	800	45.6*‡	800	41.6*‡
900	85.3*	900	77.6	900	69.1	900	59.2‡	900	49.2*‡	900	45.0*‡
1000	89.9*	1000	82.3	1000	73.5	1000	63.3‡	1000	52.6*‡	1000	48.1*‡
1100	94.4*	1100	86.7	1100	77.8	1100	67.3‡	1100	55.9*‡	1100	51.2*‡
1200	98.6*	1200	91.1*	1200	82.0*	1200	71.3*‡	1200	59.3*‡	1200	54.3*‡
1400	106.9*	1400	99.6*	1400	90.2*	1400	79.1*‡	1400	65.9*‡	1400	60.2*‡
1600	115.0*	1600	107.9*	1600	98.3	1600	86.6*‡	1600	72.3*‡	1600	66.1*‡
1703	119.1*(s)	1705	112.0*(s)	1707	102.5(s)	1710	90.6*‡(s)	1716	76.0*‡(s)	1720	69.7*‡(s)
1706	136.1‡(ℓ)	1710	131.5‡(ℓ)	1715	124.3‡(ℓ)	1719	114.1*‡(ℓ)	1724	99.7*‡(ℓ)	1726	93.0*‡(ℓ)
2000	139.7‡	2000	135.0‡	2000	127.6‡	2000	117.3*‡	2000	102.8*‡	2000	96.0*‡

† Uncertainties in the electrical resistivity are as follows:

25.00 Fe - 75.00 Ni: ±5% below 100 K, ±3% from 100 K to 400 K, ±5% above 400 K to 1703 K, and ±10% above 1703 K.
20.00 Fe - 80.00 Ni: ±5% below 1705 K and ±10% above.
15.00 Fe - 85.00 Ni: ±5% below 1707 K and ±10% above.
10.00 Fe - 90.00 Ni: ±5% below 733 K, ±7% from 733 K to 1710 K, and ±10% above 1710 K.
5.00 Fe - 95.00 Ni: ±5% below 679 K, ±7% from 679 K to 1716 K, and ±10% above 1716 K.
3.00 Fe - 97.00 Ni: ±5% below 656 K, ±7% from 656 K to 1720 K, and ±10% above 1720 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

TABLE 57. RECOMMENDED ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Fe: 1.00% (1.05 At.%) Ni: 99.00% (98.95 At.%)		Fe: 0.50% (0.53 At.%) Ni: 99.50% (99.47 At.%)		Fe: 0.00% (0.00 At.%) Ni: 100.00% (100.00 At.%)	
T	ρ	T	ρ	T	ρ
1	0.40*	1	0.21*	1	0.0032
4	0.40	4	0.21	4	0.0036
7	0.41	7	0.22	7	0.0044
10	0.41	10	0.22	10	0.0057
15	0.42	15	0.23	15	0.0090
20	0.44	20	0.24	20	0.0140
30	0.50	30	0.27	30	0.0317
40	0.58	40	0.33	40	0.0678
50	0.68	50	0.42	50	0.135
60	0.83	60	0.55	60	0.242
70	1.01	70	0.71	70	0.377
80	1.21	80	0.90	80	0.545
90	1.43	90	1.10	90	0.741
100	1.66	100	1.32	100	0.959
150	2.99	150	2.60	150	2.21
200	4.57	200	4.08	200	3.67
250	6.31	250	5.78	250	5.32
273	7.17	273	6.65	273	6.16
293	7.94	293	7.43	293	6.93
300	8.12	300	7.72	300	7.20
400	12.8	400	12.3	400	11.8
500	19.0	500	18.5	500	17.7
600	27.4	600	26.7	600	25.5
637	31.2	634	30.4	630	28.7
700	34.1	700	33.2	700	32.1
800	37.5	800	36.5	800	35.5
900	40.7	900	39.7	900	38.6
1000	43.7	1000	42.5	1000	41.4
1100	46.5*	1100	45.3*	1100	44.1
1200	49.2*	1200	48.0*	1200	46.6
1400	54.7*	1400	53.1*	1400	51.7
1600	60.1*	1600	58.5*	1600	56.9
1725	63.3* (s)	1727	61.8* (s)	1728	60.2 (s)
1727	85.8*‡ (ℓ)	1728	84.0*‡ (ℓ)	1728	82.2‡ (ℓ)
2000	88.8*‡	2000	87.0*‡	2000	85.2‡

† Uncertainties in the electrical resistivity are as follows:

1.00 Fe - 99.00 Ni: ±5% below 150 K, ±3% from 150 K to 1000 K, ±5% above 1000 K to 1725 K, and ±10% above 1725 K.
0.50 Fe - 99.50 Ni: ±5% below 150 K, ±3% from 150 K to 1000 K, ±5% above 1000 K to 1727 K, and ±10% above 1727 K.
0.00 Fe - 100.00 Ni: ±5% from 50 K to 150 K, ±3% above 150 K to 1300 K, ±5% above 1300 K to 1728 K, and ±10% above 1728 K.

‡ Provisional value.

* In temperature range where no experimental data are available.

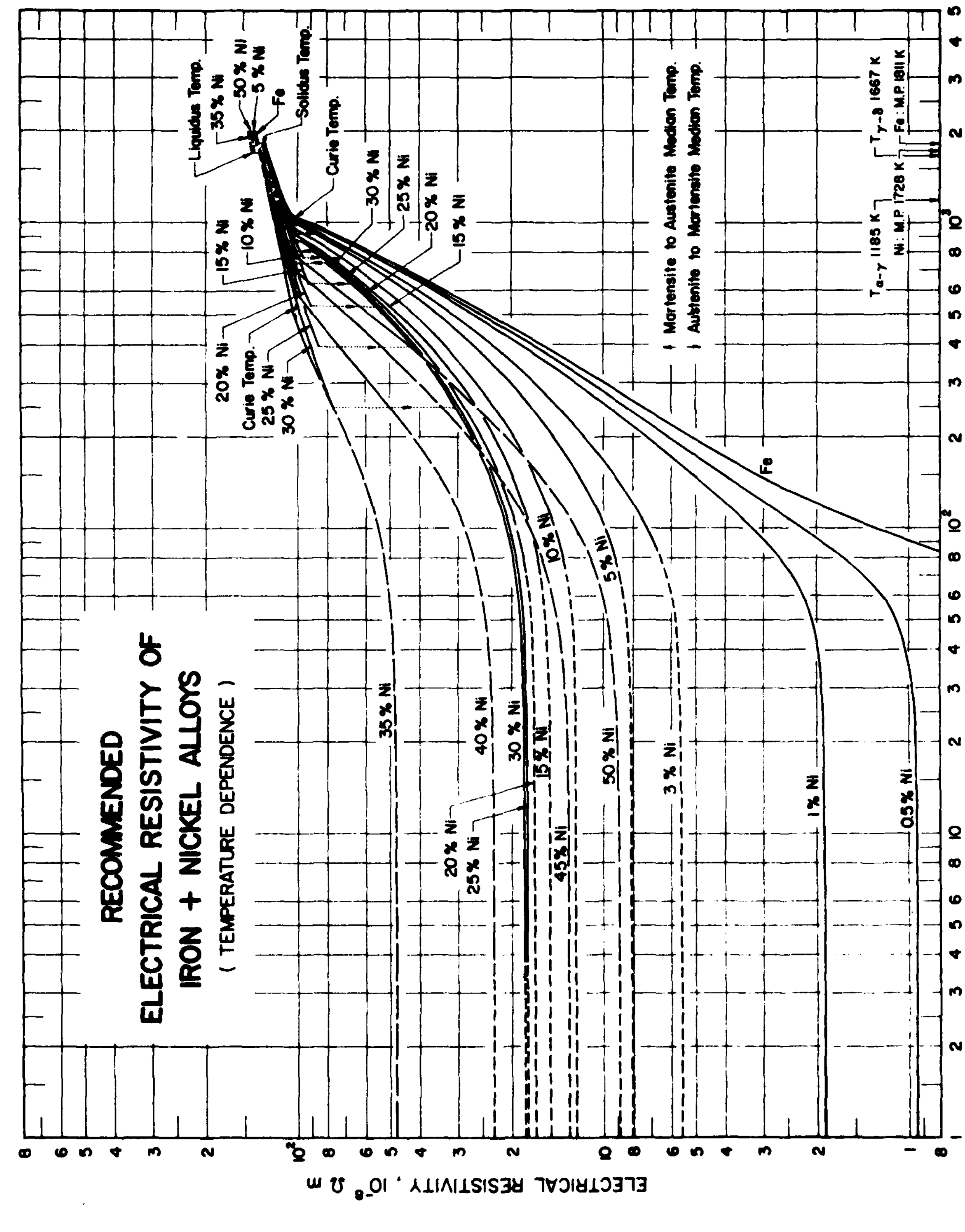

RECOMMENDED
ELECTRICAL RESISTIVITY OF
IRON + NICKEL ALLOYS
(TEMPERATURE DEPENDENCE)
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE, K
CINDAS
Liquidus Temp.
35 % Ni
50 % Ni
5 % Ni
Fe
Solidus Temp.
Curie Temp.
30 % Ni
25 % Ni
20 % Ni
15 % Ni
10 % Ni
Curie Temp.
Martensite to Austenite Median Temp.
Austenite to Martensite Median Temp.
$T_{\alpha-\gamma}$ 1185 K
Ni: M.P. 1728 K
$T_{\gamma-\delta}$ 1667 K
Fe: M.P. 1811 K
40 % Ni
45 % Ni
3 % Ni
1 % Ni
0.5 % Ni

FIGURE 43

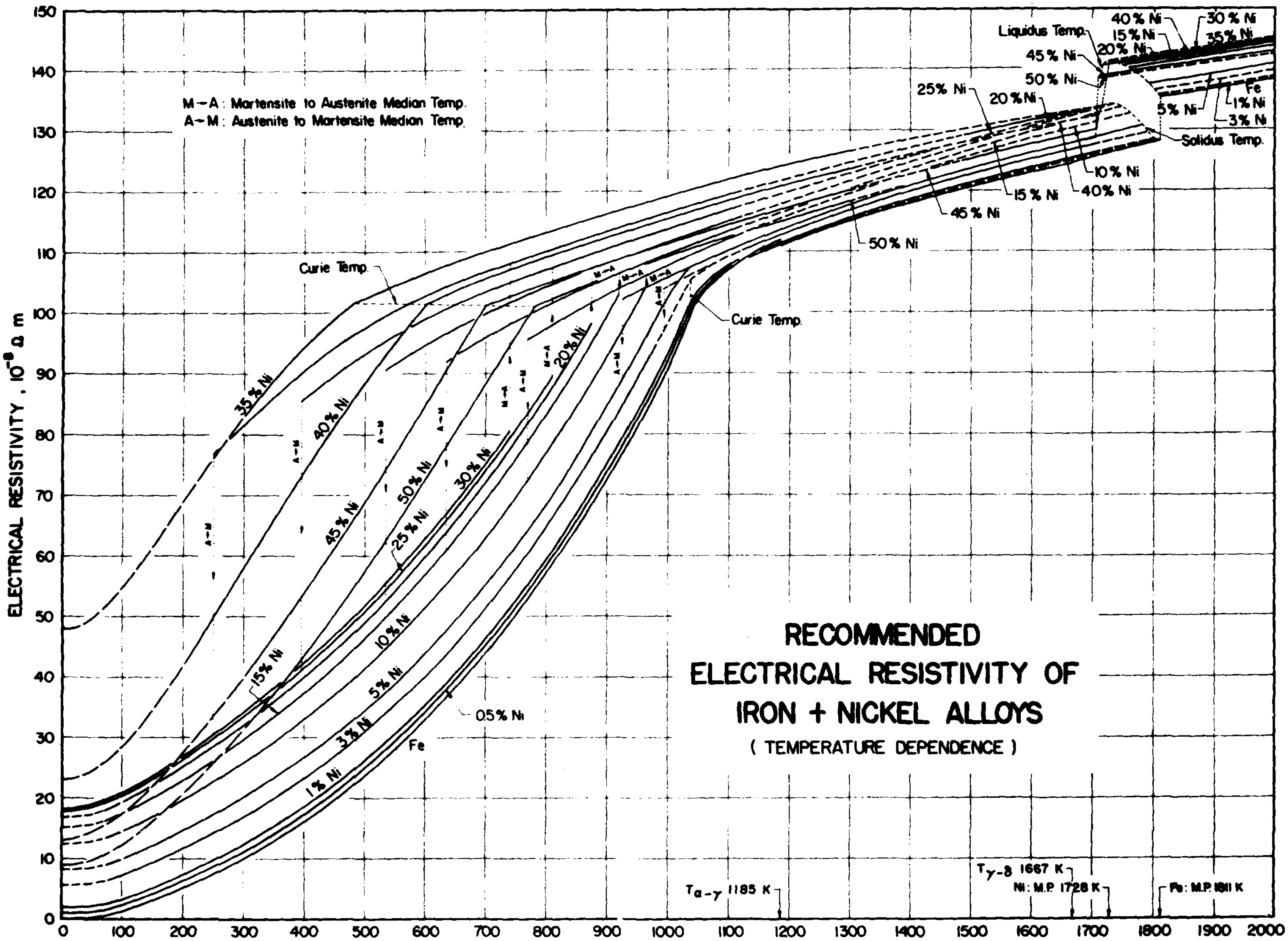

RECOMMENDED
ELECTRICAL RESISTIVITY OF
IRON + NICKEL ALLOYS
(TEMPERATURE DEPENDENCE)
M – A : Martensite to Austenite Median Temp.
A – M : Austenite to Martensite Median Temp.
ELECTRICAL RESISTIVITY , 10^{-8} Ω m
TEMPERATURE , K
CINDAS
Curie Temp.
Liquidus Temp.
Solidus Temp.
Fe
0.5% Ni
1% Ni
3% Ni
5% Ni
10% Ni
15% Ni
20% Ni
25% Ni
30% Ni
35% Ni
40% Ni
45% Ni
50% Ni
$T_{\alpha-\gamma}$ 1185 K
$T_{\gamma-\delta}$ 1667 K
Ni: M.P. 1728 K
Fe: M.P. 1811 K

FIGURE 44

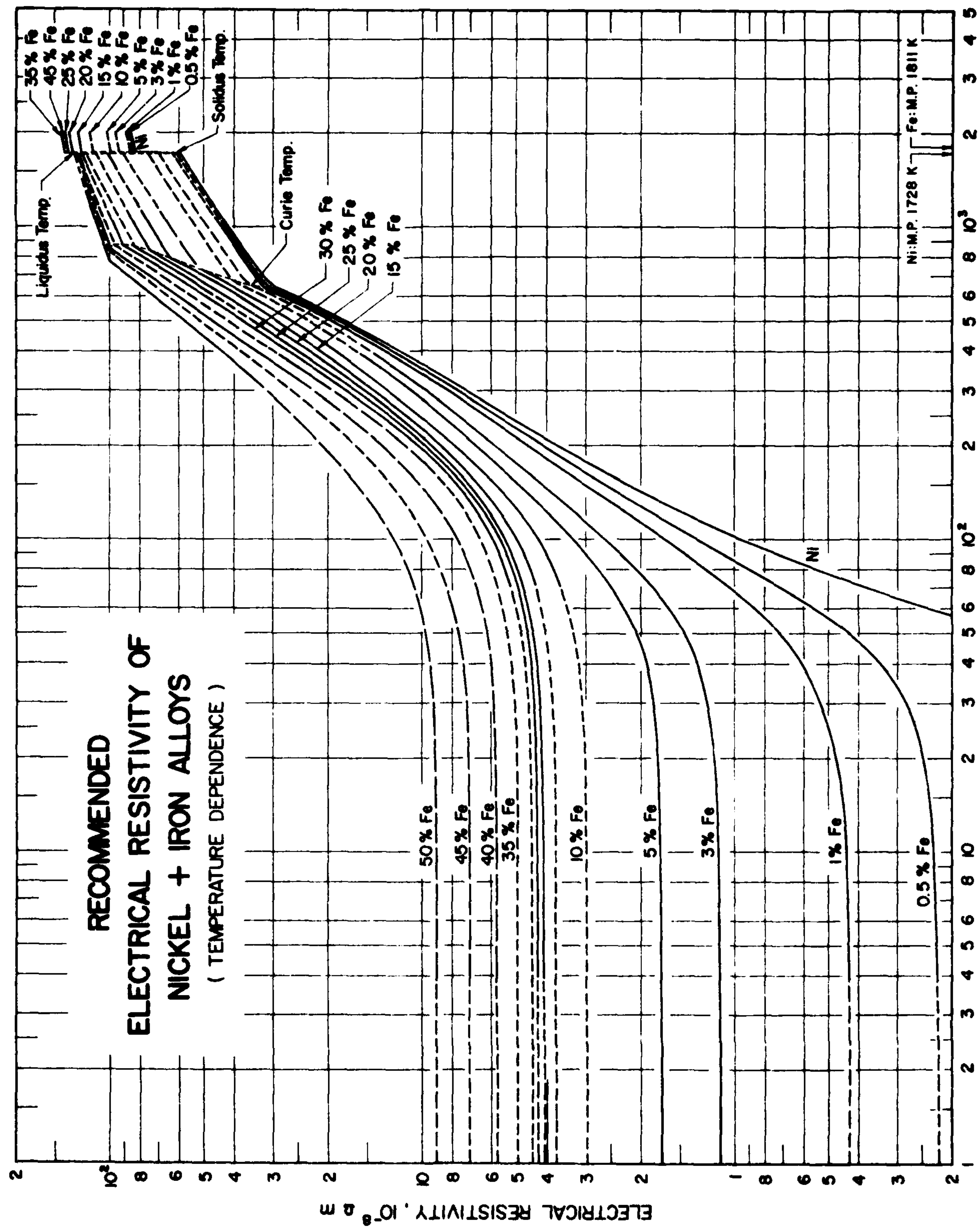

RECOMMENDED
ELECTRICAL RESISTIVITY OF
NICKEL + IRON ALLOYS
(TEMPERATURE DEPENDENCE)
Liquidus Temp.
Solidus Temp.
Curie Temp.
35 % Fe
45 % Fe
25 % Fe
20 % Fe
15 % Fe
10 % Fe
5 % Fe
3 % Fe
1 % Fe
0.5 % Fe
Ni
30 % Fe
25 % Fe
20 % Fe
15 % Fe
50 % Fe
45 % Fe
40 % Fe
35 % Fe
10 % Fe
5 % Fe
3% Fe
1% Fe
0.5 % Fe
Ni: M.P. 1728 K
Fe: M.P. 1811 K
ELECTRICAL RESISTIVITY, 10⁻⁸ Ω m
TEMPERATURE, K
CINDAS

FIGURE 45

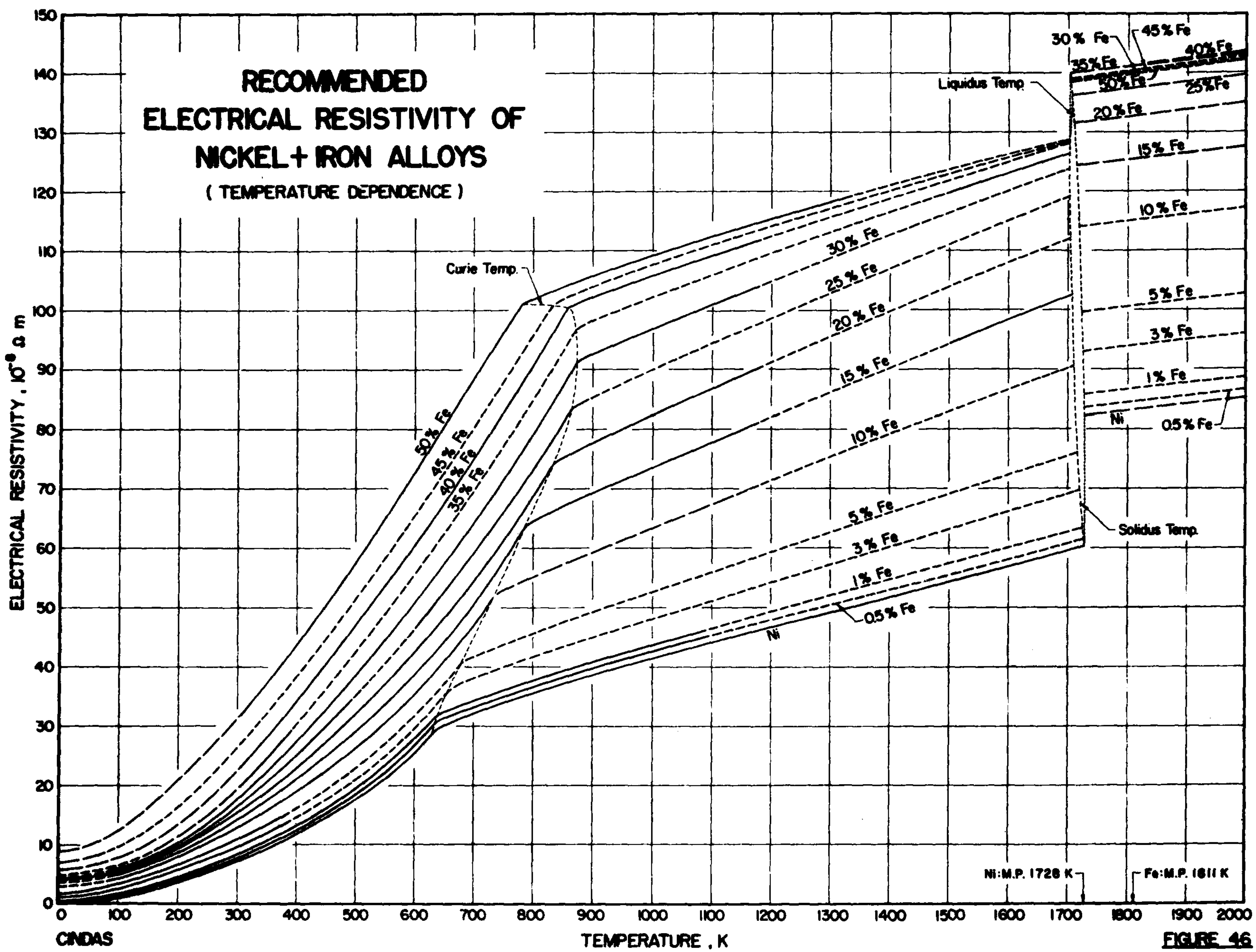

RECOMMENDED
ELECTRICAL RESISTIVITY OF
NICKEL + IRON ALLOYS
(TEMPERATURE DEPENDENCE)
ELECTRICAL RESISTIVITY, $10^{-8}\ \Omega$ m
TEMPERATURE, K
Curie Temp.
Liquidus Temp.
Solidus Temp.
50 % Fe
45 % Fe
40 % Fe
35 % Fe
30 % Fe
25 % Fe
20 % Fe
15 % Fe
10 % Fe
5 % Fe
3 % Fe
1 % Fe
0.5 % Fe
Ni
Ni: M.P. 1728 K
Fe: M.P. 1811 K
CINDAS

FIGURE 46

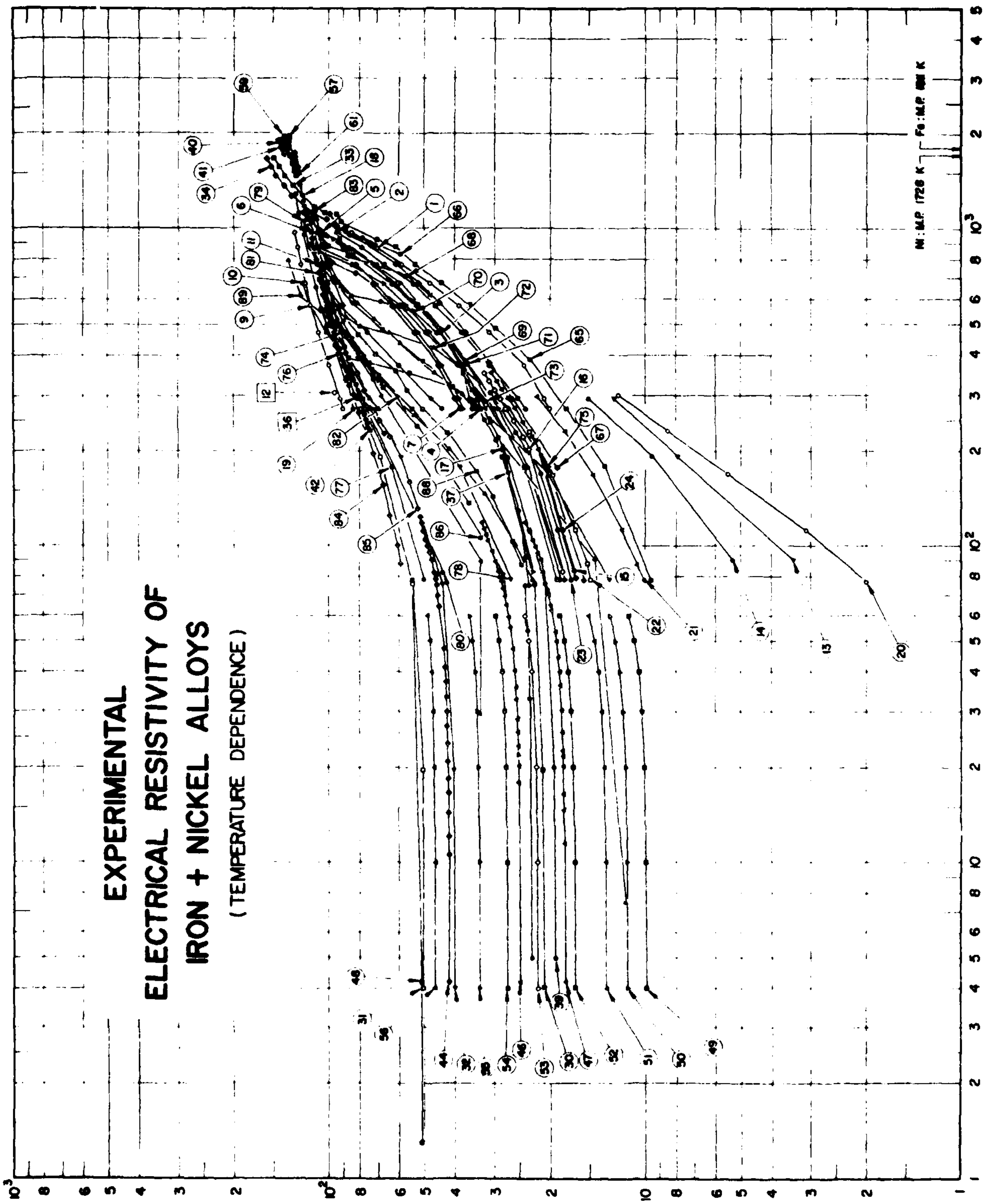

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
IRON + NICKEL ALLOYS
(TEMPERATURE DEPENDENCE)
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE, K
Ni: M.P. 1728 K
Fe: M.P. 1811 K
CINDAS

FIGURE 47

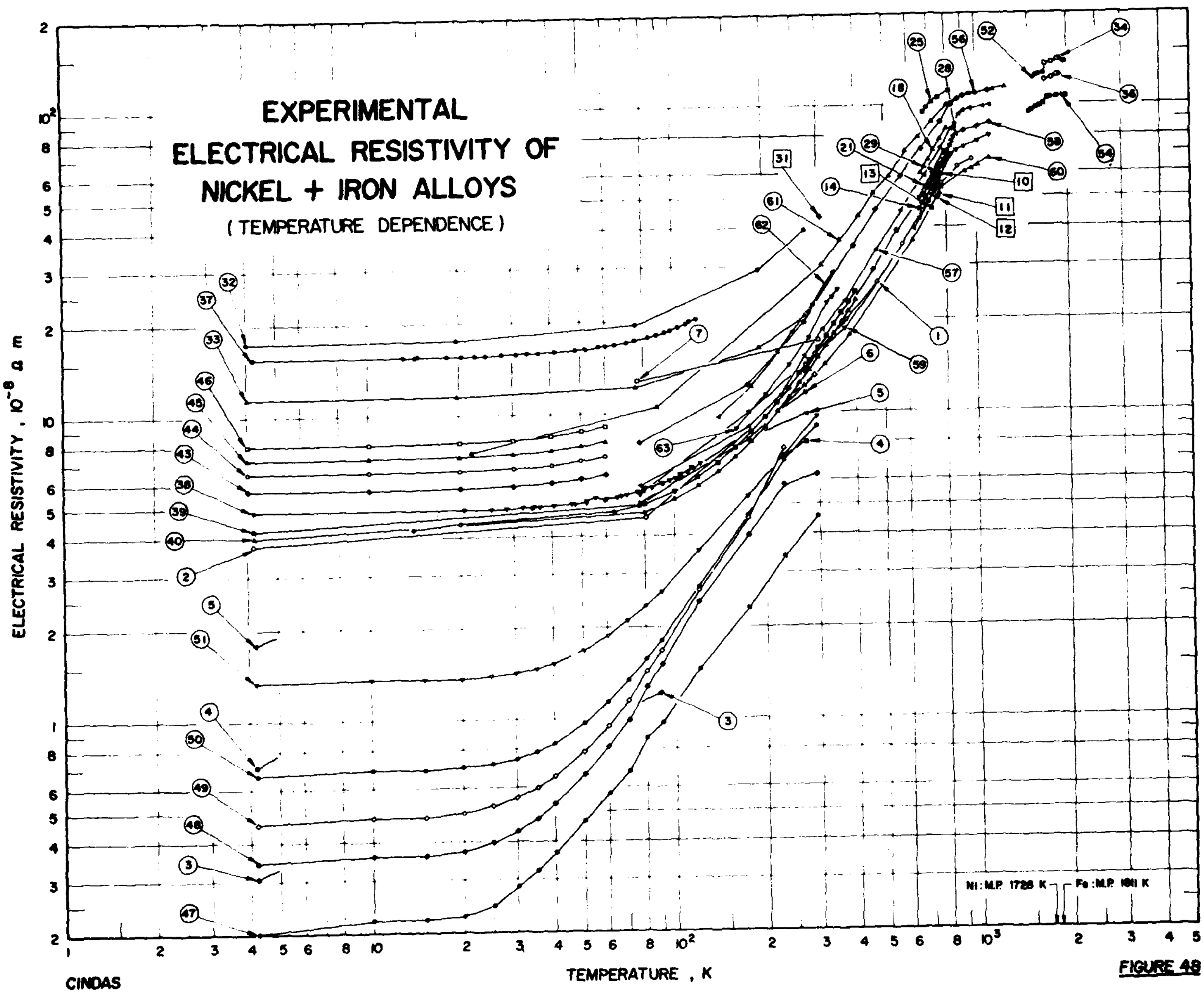

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
NICKEL + IRON ALLOYS
(TEMPERATURE DEPENDENCE)
ELECTRICAL RESISTIVITY , 10⁻⁸ Ω m
TEMPERATURE , K
Ni : M.P. 1728 K
Fe : M.P. 1811 K
CINDAS

FIGURE 48

TABLE 58. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
1	332	Ingersoll, L. R.	1920	A	273-973	150 J		4.0	Composition includes an estimated < 0.10 C; alloys prepared from doubly electro-deposited iron of 99.97 purity and electrolytic nickel of high purity; ingots formed from weighed amounts by melting in a magnesia crucible heated within a resistor furnace and subsequently forging into bars from which 1 cm bars were then machined; a measuring current of some 7.5 amps was applied; temperatures were measured with a copper-constantan thermocouple; smoothed values were reported by the author at 100 deg. intervals in figure format along with a tabulated point at 293 K; data apparently taken with increasing temp only, possible transformation to austenite at higher temperatures was not discussed.
2	332	Ingersoll, L. R.	1920	A	273-973	150 L		7.0	Similar to the above specimen.
3	332	Ingersoll, L. R.	1920	A	273-973	166 A		13.0	Similar to the above specimen.
4	332	Ingersoll, L. R.	1920	A	273-973	166 B		14.0	Similar to the above specimen.
5	332	Ingersoll, L. R.	1920	A	273-973	166 E		18.0	Similar to the above specimen.
6	332	Ingersoll, L. R.	1920	A	273-973	150 S		21.0	Similar to the above specimen.
7	332	Ingersoll, L. R.	1920	A	273-973	166 G		22.11	Similar to the above specimen except specimen composition determined by chemical analysis.
8*	332	Ingersoll, L. R.	1920	A	273-973	166 I		26.40	Similar to the above specimen.
9	332	Ingersoll, L. R.	1920	A	273-973	166 L		35.09	Similar to the above specimen.
10	332	Ingersoll, L. R.	1920	A	273-973	166 M		40.0	Similar to the above specimen except composition not determined.
11	332	Ingersoll, L. R.	1920	A	273-973	166 O		47.08	Similar to the above except specimen composition determined chemically.
12	196	Ellis, W.C., Morgan, F.L., and Sager, F.G.	1928		305	Climax	70	30	Specimen dimensions apparently about 35 cm in length x 2.5 mm in dia., electrical resistivity measurement not discussed.
13	356	Bäcklund, N.G.	1961	A	90, 193, 293			0.95	Composition reported is 0.90 at.% Ni; alloys originally supplied (circa 1920) by Heraeus, Hanau, Germany, in wire form and were kindly given for this investigation by G. Borelius; the wire was remelted and subsequently rolled into bars of 15 mm^2 cross-section x 100 mm length; the remelting was carried out in a sealed silica tube containing an argon atmosphere under 120 mm Hg pressure at room temp and placed within a graphite crucible in an induction furnace, the rolling was followed by an anneal at 1373 K for 2 hrs in an evacuated silica tube to remove any inhomogenities; subsequently the bars were rolled to final form and given a final anneal at 773 K for 10 hrs to relieve cold-work effects; separation of steel edge potential probes was measured by an optical comparator and specimen cross-section was determined from lengths, mass, and density; specimen and mount immersed directly into temperature baths (liquid oxygen, solid carbon dioxide, or ice water); electrical measurements carried out with a high-precision thermo-free potentiometer of Diesselhorst type.

* Not shown in figure.

TABLE 58. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Composition (weight percent) Ni	Composition (continued), Specifications, and Remarks
14	356	Bäcklund, N.G.	1961	A	90, 193, 293			1.90	Composition reported is 1.81 at.% Ni; preparation and measurement similar to that of the above specimen.
15	360	Kohlhaas, R. and Kierspe, W.	1965	A	83-353	10 Ni 14		3.74	Composition reported for this steel includes: 0.06 wt.% C, 0.32 wt.% Si, and 0.45 wt.% Mn; specimens heat-treated in two stages: 0.5 hr at 1123 K followed by air-cooling to 873 K for a 2 hr anneal and air-cooling to room temp; electrical resistivity measurements apparently performed in companion fashion to thermal conductivity.
16	360	Kohlhaas, R. and Kierspe, W.	1965	A	83-353	12 Ni 19		4.75	Composition reported for this steel includes: 0.086 wt.% C, 0.35 wt.% Si, and 0.40 wt.% Mn; preparation and measurement similar to the above specimen.
17	360	Kohlhaas, R. and Kierspe, W.	1965	A	83-353	X 8 Ni 9		8.35	Composition reported for this steel includes: 0.051 wt.% C, 0.28 wt.% Si, 0.74 wt.% Mn, 0.016 wt.% P, 0.006 wt.% S, 0.009 wt.% N, and 0.093 wt.% Cr; specimen heat treated in two stages: 0.5 hr at 1063 K followed by air-cooling to 843 K for a 3.5 hr anneal followed again by an air-cool to room temperature; similar in other respects to the above specimen.
18	362	Bungardt, K. and Spyra, W.	1965	A	293-1373	Ni 36		37	Composition reported for this steel includes: 0.02 wt.% C, 0.05 wt.% Si, 0.32 wt.% Mn, 0.012 wt.% P, 0.008 wt.% S, 0.08 wt.% Al, 0.05 wt.% Co, and 0.06 wt.% Mo; specimen heat treated at 1273 K for 24 hrs and water-quenched; electrical resistivity apparently measured in companion fashion along with thermal conductivity.
19	361	Griffiths, E., Powell, R.W., and Hickman, M.J.	1939	A	273-623			28.37	Composition reported for this high-alloy steel includes: 0.28 wt.% C, 0.15 wt.% Si, 0.89 wt.% Mn, 0.003 wt.% S, 0.009 wt.% P, 0.030 wt.% Cu, 0.012 wt.% Al, 0.027 wt.% As, and trace of Cr; heat treatment consisted of heating to 1223 K and water quenching; electrical resistivity measured in companion fashion with thermal conductivity; specimen current used was 10 amp, thermocouple leads serve as potential probes.
20	357	Soffer, S., Dreesen, J.A., and Pugh, E.M.	1965	A	78-302			0.42	Composition reported as nominally 0.4 at.% Ni; alloys prepared by melting weighed amounts in an induction furnace, cold-rolling to thickness and machining plates approximately 10 cm x 1 cm x 1 mm; specimens were subsequently annealed to minimize strains; probes of same composition material held in place by phosphor bronze springs on a Micarta sample holder; two thick copper sheets with a Mylar spacer acted to reduce thermal gradients; copper to alloy junctions were enclosed within copper sheaths; the electrical measurements were taken with a Wenner potentiometer and a dc null detector; sample assembly immersed directly into baths of liquid nitrogen (77K), methane (112K), ethylene (169K), propane (231K), silicone oil (room temp), and occasionally liquid argon (87K).
21	357	Soffer, S., Dreesen, J.A., and Pugh, E.M.	1965	A	78-299			5.2	Composition reported as nominal 5 at.% Ni; similar to the above specimen.

TABLE 58. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
22	357	Soffer, S., Dreesen, J.A., and Pugh, E.M.	1965	A	78-303			10.5	Composition reported as a nominal 10 at.% Ni; similar to the above specimen.
23	357	Soffer, S., et al.	1965	A	78-303			15.7	Composition reported as a nominal 15 at.% Ni; similar to the above specimen except that hot-rolling was found necessary; this was thought to be due to mixed-phase makeup of the alloy which is consistent with accepted phase diagrams, reduced electrical resistivity of this alloy thought to be due to segregation of mixed phases.
24	357	Soffer, S., et al.	1965	A	78-297			20.8	Composition reported as a nominal 20 at.% Ni; similar to the above specimen.
25*	364	Wilbur B. Driver Co.	1966		298	Niromet 48	52	48	Nominal composition; data from manufacturer's product literature.
26*	364	Wilbur B. Driver Co.	1966		298	Niromet 46	54	46	Nominal composition; data from manufacturer's product literature.
27*	364	Wilbur B. Driver Co.	1966		298	Niromet 44	56	44	Nominal composition; data from manufacturer's product literature.
28*	364	Wilbur B. Driver Co.	1966		298	Niromet 42	58	42	Nominal composition; data reported from manufacturer's product literature.
29*	364	Wilbur B. Driver Co.	1966		298	Niromet 36	64	36	Nominal composition; data reported from manufacturer's product literature.
30	103	Clark, A.F., Childs, G.E., and Wallace, G.H.	1970	A	4-273	Fe-29% Ni	~69	28.45	Composition reported for this nickel steel includes: 0.91 wt.% Si, 0.51 wt.% Mn, 0.20 wt.% Cu, and lesser amounts of S and C; alloy described as being fully austenitic and having an average grain size of 0.025 mm; specimen rough-machined from stock materials to dimensions of about 152 mm long x 6.35 mm dia, and subsequently ground flat with sides parallel to ±0.005 mm; specimen mount forms part of a dip probe to be lowered into temperature baths of liquid helium (4K), liquid hydrogen (20K), liquid nitrogen (76K), solid carbon dioxide (192K), and ice water (273K); data acquisition was fully automated to take and average nineteen successive readings; for the lower resistivity specimens a potentiometer and null detector were available enabling a resolution of a few x 10^{-8} volt.
31	103	Clark, A.F., et al.	1970	A	4-273	Invar 36	~62	35.99	Composition reported for this technical alloy includes: 0.81 wt.% Mn, 0.35 wt.% Si, 0.17 wt.% Se, and lesser amounts of C, S, and P; alloy described as being 12-15% cold-drawn and having an average grain size of 0.02 mm; similar in other respects to the above specimen.
32	103	Clark, A.F., et al.	1970	A	4-273	LR 35	~63	36.04	Composition reported for this technical alloy includes small but unspecified amounts of C, Co, Si, Cu, Al, Mn, Cr, P, S, N, and O; alloy described as being hot-rolled and having an average grain size of 0.04 mm; similar in other respects to the above specimen.
33	365	Smolin, M.D.	1966		1123-1673			2.1	Composition reported is 2 at.% Ni; no other experimental details reported.
34	365	Smolin, M.D.	1966		1073-1673			4.2	Composition reported is 4 at.% Ni; no other experimental details reported.
35*	363	Wotruba, K.	1957		294	Hipernik	51.34	48.24	Composition reported for this alloy includes 0.38 wt.% Mn and 0.04 wt.% C, as determined by the Research Inst. of V.I. Lenin Enterprise at Pilzen; wire specimens were formed 10.0 cm x 0.05 cm in dimension; specimens annealed at 1173 K in an atmosphere of technical hydrogen.

* Not shown in figure.

TABLE 58. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
36	333	Reed, R.P., Clark, A.F., and Schramm, R.E.	1971		295	Fe-29 Ni		29	Alloy heat treatment consisted of a vacuum anneal at 1323 K for 1 hr followed by an air cool to 295 K; structure reported to be fcc austenitic; a defect annealing study is reported by authors.
37	333	Reed, R.P., et al.	1971		4-295				Above specimen cooled quickly to 4 K; structure reported to be about 97% bcc martensite; electrical resistivity data collected continuously from 4 K to room temp with holds at 77 K of 6.7 hrs and at 193 K of 2 hrs; electrical resistivity values read from figure showing continuous record.
38*	333	Reed, R.P., et al.	1971		4-295				Above specimen quickly re-cooled to specimen 4 K; electrical resistivity apparently re-measured at both temperatures of liquid helium (4K), liquid nitrogen (77K), solid carbon dioxide (193K), and room temperature (295K).
39	333	Reed, R.P., et al.	1971		4-273				Above specimen aged 10 wks at room temp and again recooled to 4 K; remeasurement includes both temperatures of liquid hydrogen (20K) and ice water (273K); specimen subsequently etched and found to contain 98% martensite; total electrical resistivity change at room temp attributed martensite only; resistivity at room temp due to dislocations estimated to be only 0.1 μΩcm; resistivity recovery from 4 K up to room temp of 3.09 μΩcm suggests a concentration of point defects amounting to about 0.5 at.% being produced by the transformation.
40	349	Ono, Y. and Yagi, T.	1972	R	1749-1898			20.8	Composition reported as 20.0 at.% Ni; in liquid state; alloy specimens prepared from weighed amounts of metals having purities of 99.9% or more by melting in a vacuum induction furnace; a specimen of about 10 g contained in a recrystallized alumina crucible, 10 mm ID x 62 mm height, was suspended by a tungsten wire 0.12 mm dia; specimen heated under reduced pressure of 0.05 to 0.1 mm Hg by a graphite heating element of coaxial design in order that counter-flowing currents would contribute no net magnetic field within the specimen; density data from the literature were used to correct for volume thermal expansion; data fit to a linear temperature dependence the coefficients of which are reported as $\rho = 0.0403\ T + 78.33$ in μΩcm and C° respectively; overall probable error is stated to be ±0.5%.
41	349	Ono, Y. and Yagi, T.	1972	R	1717-1898			40.8	Composition reported as 39.6 at.% Ni; similar to the above specimen except $\rho = 0.0352\ T + 88.01$ in μΩcm and C° respectively.
42	334	Livingston, H. and Mukherjee, K.	1972	A	273-234			30.8	Composition reported as 29.7 at.% Ni; polycrystalline alloy prepared by arc melting 99.999% pure Fe (5-10 ppm C) and Ni in argon atmosphere; samples annealed at 1273 K for 24 hrs under vacuum; average grain size was 0.2 mm; flat specimen carefully cut to 1.2 x 0.5 x 0.06 cm^3; electrical circuitry achieved sensitivity of 8 x 10^{-8} volt; specimen temperature bath of dry ice and acetone was used; cooling data only are reported with a martensitic transformation temp of 234 K being reported.
43*	334	Livingston, H. and Mukherjee, K.	1972	A	263-234			30.8	Above specimen again measured at decreasing temps but in an 8.2 kOe transverse magnetic field.

* Not shown in figure.

TABLE 58. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
44	335	Armstrong, B.E. and Fletcher, R.	1972	A	4-122		62.2	37.1	Composition analysis originated from supplier and reported as 35.8 ± 1 at.% Ni, 0.4 at.% Mn, 0.3 at.% C, 0.13 at.% Co, 0.1 at.% Si, 0.07 at.% Cu, and balance Fe; alloys commercial grade and supplied in form of cold-rolled rods by Henry Wiggin and Co., Ltd., Hereford, England; specimen measured in as-received condition; electrical resistivity measured along with thermoelectric power using thermocouple leads as potential probes; data scatter at 0.2% level while overall uncertainty estimated to be ±2%; data read from figures as temperature independent and dependent resistivities which were subsequently combined.
45*	335	Armstrong, B.E. and Fletcher, R.	1972	A	4-122				Above specimen heat-treated by holding at 1373 K for 1 hr and water quenching, then annealing at 573 K for 12 hrs and at 373 K for 2 days.
46	335	Armstrong, B.E. and Fletcher, R.	1972	A	4-121		56.0	43.7	Composition analysis originated from supplier and reported as 42.4 ± 1 at.% Ni, 0.3 at.% C, 0.1 at.% Si, 0.04 at.% Cu, 0.03 at.% Mn, and balance Fe; similar to above specimen but with no heat treatment.
47	335	Armstrong, B.E. and Fletcher, R.	1972	A	4-120		49.8	49.5	Composition analysis originated from supplier and reported as 48.1 ± 1 at.% Ni, 0.5 at.% Mn, 0.2 at.% Si, 0.2 at.% C, 0.06 at.% Co, 0.05 at.% Cu, and balance Fe; similar to above specimen.
48	337	Mikhailova, G.N.	1971	A	0.4-293	Invar	35	37	Composition reported for this technical alloy includes: 0.7 wt.% Mn, 0.6 wt.% Si, and 0.25 wt.% C; the alloy was annealed in hydrogen at 633 K.
49	336	Gautier, F. and Loegel, B.	1972	A	4-60		51.8		Composition reported as 53 at.% Fe; alloy preparation reported by Cadeville and Loegel [358]: alloys prepared by melting 4N8 starting materials from Koch-light provenance in an induction furnace under argon atmosphere, ingots subsequently annealed 1 day at 1323 K and quenched, atomic structure at room temp is fcc as determined from x-ray measurements; data obtained from the expression $\rho = \rho_0 + 0.00038\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60$ K) reported by authors.
50	336	Gautier, F. and Loegel, B.	1972	A	4-60		53.8		Composition reported as 55 at.% Fe; alloy preparation and measurement similar to above specimen; data obtained from the expression $\rho = \rho_0 + 0.00043\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60$ K) reported by authors.
51	336	Gautier, F. and Loegel, B.	1972	A	4-60		55.8		Composition reported as 57 at.% Fe; alloy preparation and measurement similar to above specimen; data obtained from the expression $\rho = \rho_0 + 0.000502\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60$ K) reported by authors.
52	336	Gautier, F. and Loegel, B.	1972	A	4-60		57.8		Composition reported as 59 at.% Fe; alloy preparation and measurement similar to above specimen; data obtained from the expression $\rho = \rho_0 + 0.000557\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60$ K) reported by authors.
53	336	Gautier, F. and Loegel, B.	1972	A	4-60		59.8		Composition reported at 61 at.% Fe; alloy preparation and measurement similar to above specimen; data obtained from the expression $\rho = \rho_0 + 0.000623\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60$ K) reported by authors.
54	336	Gautier, F. and Loegel, B.	1972	A	4-60		61.3		Composition reported as 62.5 at.% Fe; alloy preparation and measurement similar to above specimen; data obtained from the expression $\rho = \rho_0 + 0.000668\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60$ K) reported by authors.

* Not shown in figure.

TABLE 58. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
55	336	Gautier, F. and Loegel, B.	1972	A	4-60		62.8		Composition reported as 64 at.% Fe; alloy preparation and measurement similar to above specimen; data obtained from the expression, $\rho = \rho_0 + 0.000725\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60$ K) reported by authors.
56	336	Gautier, F. and Loegel, B.	1972	A	4-60		64.9		Composition reported as 66 at.% Fe; alloy preparation and measurement similar to above specimen; data obtained from the expression $\rho = \rho_0 + 0.000735\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60$ K) reported by authors.
57	350	Baum, B.A., Tyagunov, G.V., Gel'd, P.V., and Khasin, G.A.	1971	R	1564-1961			5.2	Composition reported as 5 at.% Ni; data reported for both solid and liquid states in figure format; $d\rho/dT = 0.0072\ \mu\Omega$cm K^{-1} in liquid state; data in increasing temperature.
58*	350	Baum, B.A., et al.	1972	R	1940-1535				Above specimen measured at decreasing temperatures.
59	350	Baum, B.A., et al.	1972	R	1473-1960			15.6	Composition reported as 15 at.% Ni; data reported for both solid and liquid states; $d\rho/dT = 0.0034\ \mu\Omega$cm K^{-1} in liquid state; increasing temperature data.
60*	350	Baum, B.A., et al.	1972	R	1887-1499				Above specimen measured at decreasing temperatures.
61	350	Baum, B.A., et al.	1972	R	1491-1948			31.1	Composition reported as 30 at.% Ni; data reported for both solid and liquid states; $d\rho/dT = 0.0011\ \mu\Omega$cm K^{-1} in liquid state; increasing temperature data.
62*	350	Baum, B.A., et al.	1972	R	1878-1483				Above specimen measured at decreasing temperatures.
63*	350	Baum, B.A., et al.	1972	R	1527-1976			46.2	Composition reported as 45 at.% Ni; data reported for both solid and liquid states; $d\rho/dT = 0.0044\ \mu\Omega$cm K^{-1} in liquid state; increasing temperature data.
64*	350	Baum, B.A., et al.	1972	R	1919-1502				Above specimen measured at decreasing temperatures.
65	330	Shirakawa, Y.	1939	B	78-1128	No. 1	95.66		Alloys prepared from electrolytic iron and nickel supplied by Nippon-Denkai-Seitetsusho and by Monson and Co., respectively; chemical analysis of starting materials include, for iron: 0.05% Si, 0.05% P, 0.04% C, 0.02% Co, 0.02% Mn, 0.01% Al, and 0.003% S, and for nickel: 0.02% Fe, 0.01% C, 0.003% S, 0.002% Si, 0.001% P, and 0.001% Mn; weighed amounts were mixed and then melted under hydrogen atmosphere in an alumina crucible within a Tamman furnace; wire formed by drawing molten alloy up into silica capillary which was subsequently carefully broken; specimen annealed at 1273 K for 1 hr under vacuum and cooled slowly with length oriented along east-west direction; specimen dimensions 5.30 cm length x 0.0297 cm diameter; a nickel lead wire soldered to each end of specimen with pure silver; specimen plus lead wires annealed again at 1123 K under high vacuum for 1 hr and slowly cooled; specimen orientation during measurement always east-west; magneto-resistance in longitudinal fields up to 1.6 kOe also measured; electrical resistivity measurement technique is of 2-probe type; data reported in tabular form; measurements reported for increasing temperatures.
66	330	Shirakawa, Y.	1939	B	1083-832				Above specimen with cooling data reported.
67	330	Shirakawa, Y.	1939	B	78-1123	No. 2	90.07		Similar to above specimen except dimensions were 5.65 cm length x 0.0319 cm diameter; heating data reported.

* Not shown in figure.

TABLE 58. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Composition (weight percent) Ni	Composition (continued), Specifications, and Remarks
68	330	Shirakawa, Y.	1939	B	1025-615				Above specimen with cooling data reported.
69	330	Shirakawa, Y.	1939	B	78-1123	No. 3	86.04		Similar to above specimen except dimensions were 5.40 cm length x 0.0347 cm diameter; heating data reported.
70	330	Shirakawa, Y.	1939	B	1076-373				Above specimen with cooling data reported.
71	330	Shirakawa, Y.	1939	B	78-1123	No. 4	80.44		Similar to above specimen except dimensions were 6.79 cm length x 0.0445 cm diameter; heating data reported.
72	330	Shirakawa, Y.	1939	B	1121-364				Above specimen with cooling data reported.
73	330	Shirakawa, Y.	1939	B	78-1121	No. 5	75.31		Similar to above specimen except dimensions were 6.37 cm length x 0.0467 cm diameter; heating data reported.
74	330	Shirakawa, Y.	1939	B	1074-273				Above specimen with cooling data reported.
75	330	Shirakawa, Y.	1939	B	78-1123	No. 6	70.13		Similar to above specimen except dimensions were 5.02 cm length x 0.0890 cm diameter; heating data reported.
76	330	Shirakawa, Y.	1939	B	1033-178				Above specimen with cooling data reported.
77	330	Shirakawa, Y.	1939	B	78-1127	No. 7	64.96		Similar to above specimen except dimensions were 3.43 cm length x 0.0342 cm diameter.
78	330	Shirakawa, Y.	1939	B	78-1143	No. 8	60.00		Similar to above specimen except dimensions were 6.67 cm length x 0.0447 cm diameter.
79	330	Shirakawa, Y.	1939	B	78-1122	No. 9	50.11		Similar to above specimen except dimensions were 5.46 cm length x 0.0326 cm diameter.
80	338	Larikov, L.N., Usov, Yu.V., and Boychuk, I.N.	1977		4-1288			35.68	Measurement included data readings at both increasing and decreasing temperatures; data reported in figure format.
81	338	Larikov, L.N., et al.	1977		4-1281			36.9	Similar to above specimen.
82	338	Larikov, L.N., et al.	1977		4-1280			37.64	Similar to above specimen.
83	338	Larikov, L.N., et al.	1977		4-1290			44.86	Similar to above specimen.
84	343	Somura, T.	1977	C	88-672			34.1	Composition reported as 33 at.% Ni; alloys prepared by arc-melting iron and nickel rods of 99.99% purity; ingots cut into rectangular plates of dimension 0.8 x 0.4 x 0.03 cm^3; specimens annealed at 1273 K under vacuum for 5 hrs; thin copper leads spot welded to specimens; electrical measurements performed using four-probe AC technique with primary current of 0.4 amp at 30 Hz; specimen temp controlled to ±0.2 deg; data reported in combined figure format; Curie temperature reported as 456 K.
85	343	Somura, T.	1977	C	82-701			37.2	Composition reported as 36 at.% Ni; similar to above specimen with Curie temperature reported to be 511 K.
86	343	Somura, T.	1977	C	106-719			39.2	Composition reported as 38 at.% Ni; similar to above specimen with Curie temperature reported to be 588 K.
87*	343	Somura, T.	1977	C	132-630				Above specimen with $\rho^{-1}\, d\rho/dT$ determined directly from incremental measurement over 2 to 3 deg. interval.

* Not shown in figure.

TABLE 58. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
88	343	Somura, T.	1977	C	88-772			41.2	Composition reported as 40 at.% Ni; similar to above specimen except $d\rho/dT$ not measured; Curie temperature reported to be 630 K.
89	343	Somura, T.	1977	C	78-838			43.2	Composition reported as 42 at.% Ni; similar to above specimen with Curie temperature reported to be 663 K.
90*	331	Ascher, E.A.	1955	A	301-676	Ni 30		30.1	Composition as reported includes ≤ 0.02% Si; alloy prepared from weighed amounts of starting materials by melting and rolling to thin plate; specimen heat-treated at 1273 K for 2 hrs under hydrogen atmosphere, furnace quenched to 903 K, and air-cooled to room temperature; specimen temperatures measured with thermocouples and indicate temperature gradients of no more than 1.5 deg during measurements; electrical measurements performed with Diesselhorst potentiometer using shielded components; specimen immersed in liquid air for 4 hrs; data presented in tabular form.
91*	331	Ascher, E.A.	1955	A	295-763				Same specimen heated to 923 K for 50 hrs and remeasured.
92*	331	Ascher, E.A.	1955	A	303-323	Ni 31		31.4	Composition as reported includes 0.28% Si; alloy prepared as above except rolling followed by anneal at 873 K for 2 hrs and furnace cooling for 4 hrs; data reported in tabular form.
93*	325	Fert, A. and Campbell, I.A.	1976	A	1.3-44.8			1.1	Composition reported as 1 at.% Ni; alloy prepared at the CEN, Grenoble in a levitation furnace from starting materials obtained by zone melting (RRR = 700 and 25 for Ni and Fe respectively); alloy drawn into wire of 1 mm diameter and subsequently annealed at 1073 K; absence of precipitates checked by micrography; alloy analyzed by calorimetry or atomic absorption spectroscopy; accuracy generally limited by current stability ($\pm 2 \times 10^{-5}$); temperatures in helium range measured with germanium resistor to an accuracy of ±0.1 deg; total electrical resistivity recovered from tabulated residual resistivity values for both 1 at.% Ni and 2 at.% Ni combined with temperature dependent resistivity deduced from measurements on both alloys and presented as a single curve in figure format.
94*	328	Schwerer, F.C. and Cuddy, L.J.	1970	A	4-1097			0.99	Composition reported as 0.94 at.% Ni; alloys preparation not reported; specimen heated in a flowing He-2% H_2 atmosphere within a noninductively wound furnace; temperature measurement by means of thermocouple with accuracy of few degrees; measurement procedure involved simultaneous measurement of specimen and iron standard ($\rho_0 \approx 0.04$ μΩcm) thus obviating more precise temperature determination; temperature increased at about 1 deg/min during measurement; chief source of errors was geometrical factor for which precision was ±3% giving errors at high temperature of ±0.5 μΩcm; data reported as solute resistivity in figure format.

* Not shown in figure.

TABLE 58. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Fe	Ni	Composition (continued), Specifications, and Remarks
95*	329	Schwerer, F.C. and Cuddy, L.J.	1970	A	4.2-1140			0.46	Composition reported as 0.44 at.% Ni; specimen preparation not reported; specimen preparation not reported; solute concentration determined by chemical analysis; current and potential leads of iron spot welded with gauge length measured by traveling microscope; average cross-section deduced from mass, length, and density; largest sources of error thought to be geometrical factors for which uncertainties are thought to be < 0.2%; errors in solute resistivity certainly less than 0.5% resistivity of iron standard; high temperature measurements involved mounting specimen and iron standard ($\rho_0 \approx 0.04\ \mu\Omega$cm) within non-inductively wound furnace in thermal proximity of each other and of thermocouple well, atmosphere of He-2% H_2 flowed past during measurements; temperature monitored with Pt/Pt 10% Rh thermocouple; current of 0.5 amp stabilized to 1 : 10^5 was used, measurements made with temperature changing at rate of 1 deg min^{-1}; voltages amplified with Keithley 140 and measured with digital voltmeter; complete set of measurements (including specimen, standard, and reversals) could be made within temperature change of ≤ 0.2 deg; data reported as solute resistivity ($= \rho_{alloy} - \rho_{standard}$) in figure format.
96*	329	Schwerer, F.C. and Cuddy, L.J.	1970	A	4.2-1101			0.99	Composition reported as 0.94 at.% Ni; preparation and measurement similar to above specimen.

* Not shown in figure.

TABLE 59. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

T	ρ
DATA SET 1	
273	20.1
293	20.9
373	24.1
473	31.1
573	38.9
673	48.0
773	58.8
873	70.6
973	85.0
DATA SET 2	
273	23.9
293	25.2
373	31.1
473	38.0
573	46.1
673	54.1
773	67.0
873	79.0
973	94.6
DATA SET 3	
273	32.0
293	33.0
373	38.2
473	44.3
573	53.0
673	62.0
773	72.4
873	86.9
973	110.0
DATA SET 4	
273	33.2
293	33.9
373	37.8*
473	45.2*
573	53.3*
673	62.4*
773	72.7*
873	85.9*
973	108.2*
DATA SET 5	
273	35.2
293	35.9
373	37.8
473	45.3*
573	52.8*
673	63.1
773	70.8
873	90.0
973	106.4
DATA SET 6	
273	37.8
293	38.8
373	44.1
473	52.2
573	61.5
673	71.2
773	82.0
873	109.0
973	113.8
DATA SET 7	
273	38.3
293	40.0
373	45.0
473	53.5
573	62.4
673	72.4
773	82.0*
873	108.0*
973	111.6*
DATA SET 8*	
273	32.8
293	35.9
373	37.8
473	45.0
573	52.6
673	62.5
773	71.9
873	102.8
973	110.9
DATA SET 9	
273	90.0
293	92.0
373	100.0
473	108.2
573	114.8
673	119.0
773	123.0
873	126.0
973	129.0
DATA SET 10	
273	69.7
293	74.1
373	85.8
473	102.0
573	114.3*
673	121.3
773	124.6*
873	127.2*
973	129.0*
DATA SET 11	
273	44.0
293	47.5
373	60.0
473	75.5
573	92.0
673	103.0
773	108.8
873	112.0
973	114.0*
DATA SET 12	
305	95.1
DATA SET 13	
90	3.4
193	7.9
293	12.6
DATA SET 14	
90	5.3
193	9.5
293	15.1
DATA SET 15	
83	16.78
203	21.80
223	22.89
248	24.31
273	25.82
293	27.08
313	28.36
333	29.50
353	30.70
DATA SET 16	
83	18.26
203	23.43
223	24.51
248	25.96
273	27.81
293	28.78
313	29.98
333	31.19
353	32.43
DATA SET 17	
83	22.66
203	28.20
223	29.34
248	30.90
273	32.56*
293	33.96*
313	35.21
333	36.48
353	37.70
DATA SET 18	
293	78.1
373	86.8*
473	96.3
573	101.7
DATA SET 18 (cont.)	
673	105.7
773	109.0*
873	112.2*
973	115.0*
1073	117.5
1173	119.7
1273	121.8
1373	123.7
DATA SET 19	
273	84.0
323	86.8
373	89.9
423	92.9
473	95.9*
523	98.9
573	102.0*
623	104.8
DATA SET 20	
78	1.7
114	2.9
171	5.4
232	8.6
302	12.4
DATA SET 21	
78	10.1
88	10.6
112	11.8
169	14.6
232	18.2
299	22.2
DATA SET 22	
78	14.8
88	15.1
113	16.7
169	19.9
230	23.6
303	28.3
DATA SET 23	
78	17.0
113	19.0
169	22.3
230	26.0
303	30.8
DATA SET 24	
78	16.7
111	18.5
169	21.6
231	25.7
297	30.3
DATA SET 25*	
298	54.0
DATA SET 26*	
298	45.7
DATA SET 27*	
298	64.0
DATA SET 28*	
298	65.0
DATA SET 29*	
298	78.0
DATA SET 30	
4.0	20.9
19.65	21.1
75.75	22.4
192.4	28.4
273	35.4*
DATA SET 31	
4.0	50.2
19.65	50.5

* Not shown in figure.

TABLE 59. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 31 (cont.)	
75.75	54.4
192.4	69.0
273	79.5
DATA SET 32	
4.0	40.0
19.65	40.2
75.75	43.8
192.4	59.5
273	71.9
DATA SET 33	
1123	103.3
1173	111.1
1273	122.8
1373	130.4
1473	138.2
1573	143.9
1673	149.6
DATA SET 34	
1073	101.5
1123	112.7
1173	120.5*
1273	131.5
1373	139.4
1473	147.8
1573	153.0
1673	157.7
DATA SET 35*	
294	39.34
DATA SET 36	
295	81.78
DATA SET 37	
4	22.9
33	23.2
54	23.6
77	24.0
77	23.3
DATA SET 37 (cont.)	
92	24.0
130	25.2
172	27.2
193	28.2*
193	28.0*
218	29.7
252	32.3
295	35.7
DATA SET 38*	
4	19.7
77	21.0
193	27.6
295	35.2
DATA SET 39	
4	19.3
20	19.5
77	20.8
193	27.4
273	33.2*
DATA SET 40	
1749	137.8
1800	139.9
1873	142.8
1898	143.8
DATA SET 41	
1717	138.8
1800	141.8
1873	144.3
1898	145.2
DATA SET 42	
273.0	78.64*
267.8	77.98
262.8	77.53
252.9	76.63
247.8	76.24*
245.1	75.93
242.8	75.63*
240.5	75.41*
DATA SET 42 (cont.)	
238.8	75.33*
237.7	75.22
235.9	75.04*
234.3	74.87*
233.9	74.24
DATA SET 43*	
262.9	77.65
252.8	76.76
242.7	76.15
239.1	75.88
237.9	75.74
234.2	75.25
DATA SET 44	
4.2	41.7
24.8	42.26
30.0	42.46
32.9	42.61
37.5	42.86
40.5	43.06
46.6	43.46
55.3	44.11
65.4	44.96
20.0	45.46
24.1	45.86
78.1	46.31
81.2	46.66
88.8	47.52
89.8	47.72
94.9	48.32
101.0	49.07
106.1	49.72
111.2	50.47
116.8	51.13
120.3	51.78
121.8	52.03
DATA SET 45*	
4.2	43.4
27.2	43.94
32.3	44.15
37.8	44.40
39.8	44.56
52.4	45.27
DATA SET 45 (cont.)*	
60.4	45.88
70.5	46.80
81.1	47.92
91.1	49.14
103.2	50.61
112.7	51.84
121.8	53.11
DATA SET 46	
4.2	24.6
27.9	25.02
32.9	25.21
36.0	25.31
40.0	25.56
47.1	25.91
56.3	26.51
60.8	26.81
64.9	27.16
69.0	27.51
74.0	27.87
78.6	28.37
84.2	28.87
89.8	29.37
99.9	30.42
106.0	31.12
111.1	31.67
116.2	32.27
120.8	32.88
DATA SET 47	
4.2	17.2
30.9	17.74
35.5	17.94
40.0	18.14
45.1	18.24
49.7	18.54
54.7	18.74
62.3	19.14
65.4	19.29
69.4	19.59
74.5	19.89
79.1	20.04
84.7	20.54
89.2	20.89
94.3	21.34
100.4	21.84
DATA SET 47 (cont.)	
105.5	22.14
111.6	22.69
119.7	23.49
DATA SET 48	
0.4	51*
1.3	51
4.2	51
78	54.7
293	81.1*
DATA SET 49	
4.2	10.4
10	10.44
20	10.55
30	10.74
40	11.01
50	11.35
60	11.77
DATA SET 50	
4.2	12.1
10	12.13
20	12.26
30	12.48
40	12.78
50	13.17
60	13.64
DATA SET 51	
4.2	14.3
10	14.31
20	14.46
30	14.71
40	15.06
50	15.52
60	16.07
DATA SET 52	
4.2	17.4
10	17.45
20	17.61
30	17.89
DATA SET 52 (cont.)	
40	18.28
50	18.78
60	19.40
DATA SET 53	
4.2	22.3
10	22.39
20	22.58
30	22.89
40	23.33
50	23.89
60	24.57
DATA SET 54	
4.2	27.5
10	27.59
20	27.79
30	28.12
40	28.59
50	29.19
60	29.92
DATA SET 55	
4.2	34.5
10	34.57
20	34.79
30	35.15
40	35.66
50	36.31
60	37.11
DATA SET 56	
4.2	46.0
10	46.02
20	46.24
30	46.61
40	47.13
50	47.79
60	48.60

* Not shown in figure.

TABLE 59. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

DATA SET 57

T	ρ
1564	126.2
1586	127.1*
1614	128.6
1658	129.2
1689	129.4
1716	129.4*
1747	129.4
1762	129.4*
1806	134.8
1840	134.8
1862	134.5*
1890	135.1
1939	136.3
1961	135.3

DATA SET 58*

T	ρ
1940	133.9
1823	134.4
1763	134.0
1723	133.4
1684	134.9
1656	133.8
1615	127.4
1552	124.5
1535	123.3

DATA SET 59

T	ρ
1473	127.4
1529	129.5
1608	130.7
1626	131.7*
1642	130.7*
1695	132.5
1711	133.8
1778	137.5*
1806	139.8*
1862	138.2
1924	139.7
1940	138.3
1960	139.3

DATA SET 60*

T	ρ
1887	139.3
1828	139.3
1748	139.2

DATA SET 60 (cont.)*

T	ρ
1686	138.0
1668	139.2
1631	137.8
1593	136.5
1586	131.3
1551	130.3
1543	129.1
1499	127.2

DATA SET 61

T	ρ
1491	124.8
1501	125.8*
1538	127.4
1546	128.4*
1573	128.6*
1596	130.0*
1637	131.8*
1640	131.1*
1661	132.4*
1691	133.3*
1729	139.9*
1757	141.4*
1793	141.4*
1841	140.7*
1859	140.2*
1916	142.0*
1948	140.6*

DATA SET 62*

T	ρ
1878	140.7
1814	139.6
1778	141.1
1738	141.9
1706	139.3
1685	140.8
1659	139.9
1616	139.3
1555	138.1
1526	129.3
1505	127.2
1483	126.7

DATA SET 63*

T	ρ
1527	124.1
1581	125.9

DATA SET 63 (cont.)*

T	ρ
1631	127.2
1663	127.6
1695	127.5
1731	137.9
1767	137.5
1808	139.1
1847	139.6
1894	139.6
1946	139.6
1976	140.0

DATA SET 64*

T	ρ
1919	138.6
1882	139.4
1837	138.8
1792	140.2
1718	137.5
1689	137.8
1655	138.0
1614	137.2
1586	136.2
1554	126.3
1525	126.9
1502	125.0

DATA SET 65

T	ρ
78	9.60
178	13.5
273	17.8
389	23.2
484	29.8
573	35.9
675	44.1
773	53.2
872	61.8
925	70.8
993	80.4*
1021	85.8*
1033	88.3*
1044	90.7*
1054	91.6
1073	92.6*
1095	93.6*
1128	94.7

DATA SET 66

T	ρ
1083	93.2*
1025	91.2*
983	89.5
962	88.6*
953	86.9*
943	84.2*
933	78.5
923	74.1*
904	69.2*
832	59.4

DATA SET 67

T	ρ
78	14.7*
178	19.0
273	23.7*
293	26.5
378	31.1
473	37.1
581	44.7
673	52.1
773	61.8
881	74.0
954	86.0
975	89.4*
988	92.2*
1002	94.3
1033	96.4*
1061	97.3*
1123	99.4

DATA SET 68

T	ρ
1025	96.2
923	92.4
813	87.6
784	85.5*
773	84.0*
764	82.4*
754	71.8*
714	57.3
615	47.7

DATA SET 69

T	ρ
78	18.5
178	23.6
273	29.0

DATA SET 69 (cont.)

T	ρ
285	30.7*
386	37.0
483	44.1
571	53.2*
673	59.8
773	70.7*
860	84.5
913	95.4*
928	97.6
943	105.0*
955	106.2*
963	106.9*
1003	108.4
1061	111.1*
1123	112.9*

DATA SET 70

T	ρ
1076	111.3
973	107.6*
877	103.7*
774	99.0
679	93.7
641	91.6*
624	87.3*
613	84.9
611	79.5*
593	68.3
554	54.4
473	45.0
373	37.4*

DATA SET 71

T	ρ
78	19.0
178	24.1
273	30.1
293	30.9*
375	36.5
481	44.5*
571	52.2
673	61.4*
773	73.6*
822	84.3
845	89.9*
853	92.0*
875	100.6
898	104.0*

DATA SET 71 (cont.)

T	ρ
933	106.6
1023	109.7*
1123	112.9*

DATA SET 72

T	ρ
1121	111.6*
1074	110.4
974	107.2*
875	103.9
783	100.1
764	99.5*
676	95.4
573	90.0
539	89.0*
523	88.0
503	86.5*
493	79.8
473	64.2
423	46.8
364	37.4

DATA SET 73

T	ρ
78	18.1
178	23.4*
273	30.1*
269	32.1
373	38.9*
474	48.0
573	57.1
673	67.2
773	84.1
803	94.4*
823	98.8*
843	107.6
874	109.7*
972	113.6*
1070	116.6*
1121	118.0

DATA SET 74

T	ρ
1074	116.7
972	113.6*
876	110.4*
772	106.4
673	102.1

* Not shown in figure.

TABLE 59. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 74 (cont.)	
472	91.9
428	89.4
393	86.6
379	74.9
353	55.7
317	40.9
273	34.4
DATA SET 75	
78	15.7
178	20.5
273	27.2
298	33.1*
372	39.1
473	49.0
573	59.4
673	70.3*
723	82.1
744	90.5*
773	97.5
793	99.8*
823	100.5*
871	111.2*
972	114.5*
1073	117.4*
1123	120.2
DATA SET 76	
1033	116.5*
923	113.1
791	110.1
663	105.0*
523	99.5*
405	93.9
335	88.9
293	86.5*
273	74.0
228	67.1
178	24.4*
DATA SET 77	
78	50.1
178	63.4
292	79.4
364	87.3

T	ρ
DATA SET 77 (cont.)	
425	93.1*
473	96.6*
479	97.2*
493	98.0
503	98.5*
523	99.6*
571	101.9*
669	105.3*
772	108.5*
863	111.1*
970	114.0*
1068	116.5*
1127	117.9*
DATA SET 78	
78	26.6
178	38.6
273	54.8
295	60.9*
364	73.1
472	88.9
573	100.6
599	102.8*
623	104.3*
633	105.1*
645	105.9
676	107.2*
723	109.1*
774	110.9*
826	112.1
882	113.6*
973	115.9*
1084	118.4*
1124	119.6*
1143	119.9*
DATA SET 79	
78	13.0
178	20.5
273	32.2*
285	34.8
384	50.4
483	68.0
583	84.3
684	87.4

T	ρ
DATA SET 79 (cont.)	
763	109.4*
773	110.0*
783	112.2*
793	113.1*
805	113.9*
824	114.8*
876	116.1
963	118.3*
1056	120.1
1122	121.6*
DATA SET 80	
4.2	38.3*
82	44
291	79*
321	82
344	87*
366	89*
396	92*
426	95
464	100*
493	103
523	106*
561	107
591	109*
651	110
711	113*
771	113*
831	116*
891	116*
951	121
1011	121*
1063	124*
1123	125
1191	127*
1236	128*
1288	128
1266	128*
1221	128*
1161	125*
1101	125*
1041	121*
981	121*
928	119*
861	116*
806	116*
748	113*

T	ρ
DATA SET 80 (cont.)	
681	113*
628	110*
576	103*
531	98*
486	94*
441	88*
389	82*
351	79*
306	73*
DATA SET 81	
4.2	30.6*
89	33
298	68
335	73
365	77*
394	82
424	86*
454	89
484	92*
514	95
558	101*
618	103
677	108*
722	109
782	111*
841	112*
894	114
953	115*
1005	118
1065	118*
1117	120*
1169	120*
1221	121
1281	123*
1251	123*
1192	123*
1147	121*
1095	120*
1035	118*
976	117*
923	115*
864	113*
812	112*
752	109*
700	109*
648	106*

T	ρ
DATA SET 81 (cont.)	
588	103*
528	98*
499	89*
439	83*
402	74*
357	68*
305	63*
DATA SET 82	
4.2	24.8*
82	28
297	61
327	64*
349	70
372	74*
394	77
424	82*
453	85
483	88*
513	91
535	95*
572	98*
625	101*
677	104*
736	107
803	109*
878	110*
938	110*
990	113*
1049	115
1109	115*
1169	116*
1221	116*
1280	116*
1243	116*
1191	117*
1139	116*
1072	115*
1019	113*
960	112*
906	112*
833	110*
774	107*
714	107*
654	103*
595	100*
550	89*

T	ρ
DATA SET 82 (cont.)	
491	85*
439	77*
401	71*
357	64*
305	55*
DATA SET 83	
4.2	11.3*
90	15
302	38
324	41*
354	47
377	52*
407	55*
437	60
475	64*
498	67*
520	73
550	77*
581	82
611	86*
656	92
709	98*
762	102
822	105*
890	106
950	108*
1018	109*
1078	111*
1146	112
1192	112*
1237	114*
1290	115*
1267	117*
1222	114*
1161	114*
1109	112*
1048	111*
988	109*
920	108*
860	106*
799	103*
739	102*
679	95*
633	89*
588	86*
603	79*

* Not shown in figure.

TABLE 59. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

DATA SET 83 (cont.)

T	ρ
550	71*
505	63*
445	54*
385	42*
339	36*
302	32*

DATA SET 84

T	ρ
88	59.7
100	61.0
106	62.2*
119	63.5*
125	64.8
138	65.4*
144	66.0*
156	67.3
166	68.6*
178	69.8*
184	71.1*
197	72.4
203	73.7*
216	74.3*
228	76.2*
234	76.8*
247	78.1*
259	79.4*
266	80.0
278	81.3*
284	82.5*
300	83.8
325	86.3*
331	87.6*
344	87.6
356	88.9*
366	89.5*
381	90.8*
388	91.4
397	92.1*
409	93.3*
419	93.3*
425	94.6*
438	95.2*
450	96.5
463	97.1*
475	97.8*
484	98.4*
494	99.0*

DATA SET 84 (cont.)

T	ρ
506	99.7
519	99.7*
531	101.0*
544	101.0*
556	102.2
569	102.2*
594	103.5*
606	103.5*
619	104.8*
641	105.4*
650	105.4*
659	106.7*
672	106.7*

DATA SET 85

T	ρ
82	46.9
94	48.2*
104	48.8*
116	50.7*
132	52.6
148	53.3*
160	55.8
179	58.3*
191	59.6*
207	62.1*
223	64.6
235	66.5*
251	69.1
263	71.0*
273	72.2*
285	73.5*
298	76.0*
310	77.3
323	79.2*
335	81.1*
351	81.7
360	83.6*
373	84.9*
389	86.1*
401	87.4*
407	88.7
426	89.9*
445	91.2
454	92.5*
470	93.7*
479	94.3*
489	95.0*

DATA SET 85 (cont.)

T	ρ
498	96.2*
517	96.9*
529	98.1*
542	98.8*
548	99.4
561	99.4*
573	100.0*
586	100.6*
601	101.3*
617	101.9*
639	102.5*
658	103.1*
673	104.4*
701	105.0

DATA SET 86

T	ρ
106	33.0
125	34.9*
138	36.2
150	37.5*
163	40.0*
172	41.3*
178	42.5*
191	43.8*
197	46.3*
209	47.6*
222	49.5*
228	51.4*
241	52.7
253	55.2*
259	56.5*
272	57.8*
278	59.7*
288	61.6*
297	62.9*
303	65.4*
319	67.3
331	68.6*
338	70.5*
350	72.4
359	73.7*
372	75.6*
381	77.5*
388	78.7*
403	80.0*
409	81.9
422	83.2*

DATA SET 86 (cont.)

T	ρ
431	84.4*
444	85.7*
447	87.0*
463	89.5*
481	92.1*
494	93.3
506	94.6*
512	95.2*
522	95.9*
538	97.1*
544	98.4*
556	99.7*
566	100.3*
575	101.6*
594	102.2
606	102.9*
616	104.1*
628	104.1*
641	105.4*
647	104.8*
659	105.4*
672	106.0*
691	107.3
694	107.3*
709	107.9*
719	107.9*

DATA SET 87*

T	$\rho^{-1}\, d\rho/dT$
132	0.310
147	0.314
161	0.315
207	0.308
236	0.302
261	0.291
287	0.278
303	0.273
354	0.238
372	0.227
390	0.201
407	0.201
425	0.168
468	0.141
506	0.097
535	0.068
566	0.044
586	0.031

DATA SET 87 (cont.)*

T	$\rho^{-1}\, d\rho/dT$
608	0.011
630	0.011

DATA SET 88

T	ρ
88	24.8
94	25.4*
104	26.0
113	27.3*
125	28.6*
144	30.5
154	31.7*
163	33.0*
173	34.3
185	35.6*
194	37.5*
204	39.4*
216	41.3*
229	42.5
242	45.1*
254	47.6*
263	48.9*
273	50.2
279	50.8*
289	52.1*
295	53.3*
311	56.5*
326	59.7*
332	61.0*
345	62.2*
358	64.1*
364	65.4*
376	67.9*
386	69.2*
395	70.5*
405	71.7
414	73.7*
427	75.6*
433	76.8*
449	79.4*
464	80.6
477	83.2*
489	84.4*
496	86.3*
508	87.6*
514	89.5*
530	90.8*
536	91.4*

DATA SET 88 (cont.)

T	ρ
552	93.3*
565	95.2*
580	95.9*
596	97.8*
615	99.0*
621	99.7*
630	101.0*
649	101.6
668	102.9*
681	104.1*
696	104.1*
703	104.1*
712	104.1*
718	105.4*
743	105.4
762	107.3*
772	107.3*

DATA SET 89

T	ρ
78	22.8
88	24.1*
100	25.9
112	27.2*
131	29.7*
147	32.3*
172	35.4*
188	38.0*
203	41.8
222	44.9*
244	48.7*
266	53.8
288	58.2*
312	63.3*
331	69.6
353	74.1*
372	78.5*
403	84.8*
422	90.5*
444	94.3*
481	101.9*
500	105.7
534	111.4*
563	115.8*
591	119.6*
618	123.4
628	124.7*
641	125.9*

* Not shown in figure.

TABLE 59. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF IRON + NICKEL ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 89 (cont.)	
653	127.2*
669	128.5*
678	129.7*
691	130.4*
716	131.6*
738	132.3*
753	133.5*
769	134.8*
797	135.4
812	136.1*
838	136.7*
DATA SET 90*	
301	30.5
384	37.0
460	44.7
489	47.4
563	54.4
619	59.7
695	69.5
761	85.2
876	109.4
DATA SET 91*	
295	82.4
374	88.0
433	92.1
491	95.3
565	99.0
583	99.9
601	100.6
619	101.5
636	102.2
664	103.6
696	104.7
763	107.6
DATA SET 92*	
303	86.6
313	88.3
323	89.9

T	ρ
DATA SET 93*	
1.3	1.9
3.01	1.9002
4.15	1.9004
5.21	1.9005
6.54	1.9008
7.89	1.9013
12.4	1.9039
13.7	1.9046
16.2	1.9072
18.5	1.9105
23.2	1.9205
28.0	1.9349
37.1	1.9836
44.8	2.086
DATA SET 94*†	
4.2	2.05
31	2.05
61	2.16
76	2.27
98	2.35
121	2.47
188	2.62
233	2.66
278	2.73
307	2.81
382	2.81
479	2.81
561	2.69
666	2.50
748	2.04
792	1.88
836	1.77
896	1.46
941	1.16
978	1.16
1016	0.96
1051	0.50
1097	0.35
DATA SET 95*†	
4.2	1.17
304	1.54
347	1.57
383	1.58

T	ρ
DATA SET 95 (cont.)*†	
427	1.63
459	1.63
491	1.63
531	1.59
607	1.50
646	1.45
686	1.40
733	1.36
776	1.32
826	1.25
866	1.24
902	1.18
949	1.18
1025	1.16
1039	1.23
1043	0.99
1071	0.77
1107	0.70
1140	0.61
DATA SET 96*†	
4.2	2.05
300	2.80
373	2.94
424	3.05
478	2.91
566	2.77
613	2.66
664	2.56
700	2.28
751	2.21
788	2.07
809	2.00
831	1.86
868	1.68
904	1.57
922	1.47
940	1.40
962	1.33
984	1.29
1006	1.15
1031	1.08
1050	0.73
1068	0.52
1090	0.52
1101	0.52

* Not shown in figure.
† Solute resistivity.

TABLE 60. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF NICKEL + IRON ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Fe	Composition (continued), Specifications, and Remarks
1	332	Ingersoll, L.R.	1920	A	273-293	173W	90.0		Composition includes an estimated < 0.10% C; alloys prepared from doubly electro-deposited iron of 99.97% purity and electrolytic nickel of high purity; ingots formed from weighed amounts by melting in a magnesia crucible heated within a resistor furnace and subsequently forged into bars from which 1 cm bars were machined; a measuring current of some 7.5 amps was applied; temperatures were measured with a copper-constantan thermocouple; smoothed values were reported at 100 deg. intervals in figure format along with a tabulated room temp value.
2	359	Berger, L. and Rivier, D.	1962	A	4, 80, 293		85.2	14.8	Alloy prepared from starting materials obtained from Johnson-Matthey by melting weighed amounts in a high-frequency furnace while under a vacuum of 10^{-3} torr in an alumina crucible; melting procedure repeated to improve alloy homogeniety; specimen cut to dimensions of 51 mm long x 2 mm dia and subsequently annealed at 1173 K for 2 hrs under vacuum followed by a furnace-cool of 150 deg hr^{-1} down to 433 K, a treatment sufficient to assure a disordered state; composition determined by x-ray fluorescence; specimen immersed into temperature baths of liquid helium (4K) and liquid air (80K); electrical measurements performed with Diesselhorst potentiometer.
3	326	Farrell, T. and Greig, D.	1968	A	4-89			0.8	Composition reported as 0.8 at.% Fe; alloys prepared by chill-casting under vacuum; iron content obtained from x-ray fluorescence measurement; length/area ratio determined from length, density, and mass to better than ±0.6%; data reported as temperature independent and temperature dependent resistivities presented in table and figure formats respectively; subsequent to data reading the total resistivity was formed and is given here.
4	326	Farrell, T. and Greig, D.	1968	A	4-273			1.7	Composition reported as 1.8 at.% Fe; similar to above specimen.
5	326	Farrell, T. and Greig, D.	1968	A	4-273			4.4	Composition reported to be 4.6 at.% Fe was obtained from residual resistivity measurement; similar in other respects to specimen above.
6	220	Van Elst, H.C. and Gorter, C.J.	1954	A	14-273		76	24	Alloys kindly prepared and given by Laboratories of the Philips Lampworks, Eindhoven; polycrystalline rod specimens about 20 mm length x 1 mm^2 area; electrical measuring instrumentation included a Diesselhorst compensator and a Zernike galvanameter; relative accuracy of resistance measurement was 1 part in 10^4; data reported in tabular form.
7	366	Matsumoto, G., Satoh, T., and Iida, S.	1966		77, 293	Permalloy	80	20	Thin film specimens kindly prepared in Japan's Overseas Radio and Cable System Laboratory; films of thickness 600 Å, 1200 Å, and 3000 Å were prepared during the same evaporation run; the electrical resistivity of the three films agreed within ±5% over the measured temperature range.
8*	366	Matsumoto, G. et al.	1966		293	Permalloy	80	20	Bulk specimen prepared from Permalloy material.

* Not shown in figure.

TABLE 60. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF NICKEL + IRON ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Fe	Composition (continued), Specifications, and Remarks
9*	347	Wakelin, R.J. and Yates, E.L.	1953	A	783		75.9		Composition reported is 75 at.% Ni; alloys prepared from 99.94% pure nickel and iron containing 0.7% oxygen by melting weighed amounts in pure alumina crucible under vacuum within a high-frequency induction furnace; rapid melting under pressure too low for an electrodeless discharge to occur resulted in minimal impurity uptake as evidenced by chemical analyses typically showing ≤0.2% total impurities; alloys were hot-forged and then homogenized at 1473 K for 18 hrs; subsequent photomicrographs showed uniform composition throughout; specimens were machined to dimensions of 10 cm x 4 mm x 1 mm with cross-section uniform to ±0.02 mm in either dimension; reproducibility of measurements indicated ±0.5% uncertainty; specimen chamber temperature was controlled to within 0.5 deg; specimen disordered by heating to 873 K for 12 hrs followed by rapid cooling to measuring temperature and holding for anneal times up to 48 hrs.
10	347	Wakelin, R.J. and Yates, E.L.	1953	A	773				Similar to above specimen except annealing temperature is lower and measurements span up to 50 hrs.
11	347	Wakelin, R.J. and Yates, E.L.	1953	A	763				Similar to above specimen except annealing temperature is lower and measurements span up to 164 hrs.
12	347	Wakelin, R.J. and Yates, E.L.	1953	A	753				Similar to above specimen except annealing temperature is lower and measurements span up to 164 hrs.
13	347	Wakelin, R.J. and Yates, E.L.	1953	A	722				Similar to above specimen except annealing temperature is lower and measurements span up to 117 hrs.
14	347	Wakelin, R.J. and Yates, E.L.	1953	A	662-828		75.9		Similar to above specimen through the 873 K anneal; measurement sequence involved cooling rate of 70 deg hr^{-1}.
15*	347	Wakelin, R.J. and Yates, E.L.	1953	A	675-803				Similar to above specimen except cooling rate was 1.3 deg hr^{-1}.
16*	347	Wakelin, R.J. and Yates, E.L.	1953	A	691-814				Similar to above specimen except cooling rate was 0.29 deg hr^{-1}.
17*	347	Wakelin, R.J. and Yates, E.L.	1953	A	666-783				Similar to above specimen except cooling rate was 0.10 deg hr^{-1}.
18	347	Wakelin, R.J. and Yates, E.L.	1953	A	667-806		71.0		Composition reported as 70 at.% Ni with total impurity content of ≤0.20%; preparation and measurement sequence similar to above specimen with cooling rate of 70 deg hr^{-1}.
19*	347	Wakelin, R.J. and Yates, E.L.	1953	A	684-804				Similar to above specimen except cooling rate was 1.3 deg hr^{-1}.
20*	347	Wakelin, R.J. and Yates, E.L.	1953	A	682-799				Similar to above specimen except cooling rate was 0.29 deg hr^{-1}.
21*	347	Wakelin, R.J. and Yates, E.L.	1953	A	663-762		80.8		Composition reported as 80 at.% Ni with total impurity content of ≤0.20%; preparation and measurement sequence similar to above specimen with cooling rate of 70 deg hr^{-1}.
22*	347	Wakelin, R.J. and Yates, E.L.	1953	A	659-798				Similar to above specimen except cooling rate was 1.3 deg hr^{-1}.

* Not shown in figure.

TABLE 60. MEASUREMENT INFORMATION OF THE ELECTRICAL RESISTIVITY OF NICKEL + IRON ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Fe	Composition (continued), Specifications, and Remarks
23*	347	Wakelin, R.J. and Yates, E.L.	1953	A	676-801				Similar to above specimen except cooling rate was 0.29 deg hr^{-1}.
24*	347	Wakelin, R.J. and Yates, E.L.	1953	A	671-775				Similar to above specimen except cooling rate was 0.10 deg hr^{-1}.
25*	347	Wakelin, R.J. and Yates, E.L.	1953	A	683-831		51.3		Composition reported as 50 at.% Ni with total impurity content ≤ 0.20%; preparation and measurement sequence similar to above specimen with cooling rate of 60 deg hr^{-1}.
26*	347	Wakelin, R.J. and Yates, E.L.	1953	A	704-863				Similar to above specimen except cooling rate was 1.4 deg hr^{-1}.
27*	347	Wakelin, R.J. and Yates, E.L.	1953	A	685-801				Similar to above specimen except cooling rate was 0.29 deg hr^{-1}.
28	345	Källback, O.	1947	A	631-877		75.93		Composition reported as 75 at.% Ni; alloy prepared at Kungl. Tekn. Högskolan, Stockholm, by a method typically resulting in a carbon-free nickel; weighed amounts of metals melted in a high-frequency furnace in an evacuated and sealed quartz tube which had been placed within a graphite cylinder heating element; weighing accuracy of ±0.02% and a preparation loss of 0.3% result in composition uncertainty of about 0.1%; spectrographic analysis carried out after all measurements showed 0.04% Cu, 0.01% Ca, 0.01% Mg, <0.01% Si, and <0.01% Co; ingot cold-rolled subsequent to remelting in quartz from dimensions of 16 mm length x 2 mm diameter down to an 0.8 mm square bar following which a homogenization at 1223 K for 18 hrs was carried out; specimen dimensions: 25 mm length x 0.8 mm x 0.8 mm; Pt/Pt - 10% Rh thermocouple leads served as potential probes; for measurement, the specimen was sealed into a glass tube which was kept diffusion pumped; uncertainty in resistivity estimated at ±2 to ±3%; temperature differences along specimen ≤0.2 deg and specimen enclosure temperature to within a degree; thermal history consisted of heating to 833 K, cooling to 763 for 24 hrs, then to 753 K for 4 days, to 723 K for 2 days and to 623 K for a time, all the while taking data for the ordered state; a critical point at 729 K and a Curie point at 859 K were deduced from the data.
29	345	Källback, O.	1947	A	703-877		75.93		Same specimen reheated to 783 K followed by cooling at a rate of 1 deg/min down to 703 K for measurements on the disordered state.
30*	364	Wilbur B. Driver Co.	1966		298	Balco	70	30	Nominal composition; data reported from manufacturer's product literature.
31	364	Wilbur B. Driver Co.	1966		298	Niron 52	51	49	Nominal composition; data reported from manufacturer's product literature.

* Not shown in figure.

TABLE 60. MEASUREMENT INFORMATION OF THE ELECTRICAL RESISTIVITY OF NICKEL + IRON ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Fe	Composition (continued), Specifications, and Remarks
32	103	Clark, A.F., Childs, G.E., and Wallace, G.H.	1970	A	4-273	Fe-50 Ni	50.39	~48	Composition reported for this nickel steel includes: 0.4 wt.% Mn, 0.28 wt.% Si, and lesser amounts of Cr, Co, C, Mo, P, and S; alloy described as being annealed and having an average grain size of 0.07 mm; specimen rough-machined from stock materials to dimensions of about 152 mm long x 6.35 mm diameter and subsequently ground flat with sides parallel to ±0.005 mm; specimen mount formed part of a dip probe to be lowered into temperature baths of liquid helium (4K), liquid hydrogen (20K), liquid nitrogen (76K), solid carbon dioxide (192K), and ice water (273K); data acquisition fully automated to record and average nineteen successive readings; for lower resistivity specimens a potentiometer and null detector were available enabling a resolution of a few x 10^{-8} volt.
33	103	Clark, A.F., et al.	1970	A	4-273	Fe-29 Ni	78.63	~20	Composition reported for this nickel steel includes: 0.51 wt.% Mn, 0.19 wt.% Si, and lesser amounts of C, Mo, P, and S; alloy described as being hot-rolled and having an average grain size of 0.015 mm.
34	349	Ono, Y., and Yagi, T.	1972	R	1702-1898		61.0		Composition reported as 59.8 at.% Ni; in liquid state; alloy specimens prepared from weighed amounts of metals having purities 99.9% or better by melting in a vacuum-induction furnace; a specimen of about 10 g contained in a recrystallized alumina crucible, 10 mm in I.D. x 62 mm in height, was suspended by a tungsten wire 0.12 mm in diameter; specimen heated under reduced pressure of 0.05 to 0.1 mm Hg by a graphite heating element of coaxial design such that counter-flowing currents would contribute no net magnetic field within the specimen; density data from literature used to correct for volume thermal expansion; data fit to a linear temperature dependence the coefficients of which are reported as $\rho = 0.0232\ T + 102.28$ in. $\mu\Omega$cm and C° respectively; overall probable error stated to be ±0.5%.
35*	349	Ono, Y., and Yagi, T.	1972	R	1707-1898		75.3		Composition reported as 74.4 at.% Ni; similar to above specimen except $\rho = 0.0259\ T + 83.67$ in. $\mu\Omega$cm and C° respectively.
36	349	Ono, Y., and Yagi, T.	1972	R	1710-1898		80.3		Composition reported as 79.5 at.% Ni; similar to above specimen except $\rho = 0.0396\ T + 61.46$ in. $\mu\Omega$cm and C° respectively.
37	335	Armstrong, B.E. and Fletcher, R.	1972	A	4-122		52.1	47.2	Composition originated from supplier and reported as 50.7 ±0.6 at.% Ni, 0.5 at.% Mn, 0.3 at.% C, 0.1 at.% Si, 0.07 at.% Co, 0.04 at.% Cu, and balance Fe; commercial grade alloy supplied in form of cold-rolled rods by Henry Wiggin and Co., Ltd., Hereford, England; specimen measured in as-received condition; electrical resistivity measured along with thermoelectric power using thermocouple leads as potential probes; data scatter at 0.2% level while overall uncertainty estimated to be ±2%; data read from figures as temperature independent and dependent resistivities which were subsequently combined.
38	335	Armstrong, B.E. and Fletcher, R.	1972	A	4-121		75.9	24.1	Composition reported as 75.0±1 at.% Ni and balance Fe; alloy prepared from 99.9% starting materials; specimen heat-treatment consisted of heating to 1273 K for 1 hr and cooling to 873 K at 100 deg hr^{-1} followed by a hold at 873 K for 8 hrs and water quenching; measurement procedure similar to that for above specimen.

* Not shown in figure.

TABLE 60. MEASUREMENT INFORMATION OF THE ELECTRICAL RESISTIVITY OF *NICKEL + IRON ALLOYS* (*Temperature Dependence*) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Fe	Composition (continued), Specifications, and Remarks
39	346	Moore, J.P., Kollie, T.G., Graves, R.S., and McElroy, D.L.	1971	A	4-400	Ni_3Fe:D1	75.4	24.2	Composition as reported includes < 0.05 wt.% Al, 0.02 wt.% Cu, < 0.02 wt.% Co, < 0.02 wt.% Cr, < 0.02 wt.% Mn, < 0.02 wt.% V, < 0.01 wt.% Si, < 0.01 wt.% Ti, 0.0088 wt.% O_2, 0.0023 wt.% N_2, 0.0020 wt.% C, and 0.0002 wt.% H_2; alloy prepared from stock materials with contaminant levels no higher than 450 ppm (nickel stock) and 1050 ppm (iron stock); weighed amounts of metals melted repeatedly to insure homogenization and drop-cast into a 2.5 cm diameter, water-cooled copper mold; casting received surface maching and subsequently swaged to about 0.33 cm; 7.5 cm section of rod was cut and lapped to diametrical tolerance of ±0.00025; rod wrapped in tantalum foil, encapsulated in a quartz tube under 10^{-7} mm Hg vacuum and heat-treated by annealing at 1375 K for 24 hrs followed by an ice-water quench; specimen considered to be completely disordered; most probable uncertainty in measured electrical resistivity was ±0.3%; data presented in tabular form.
40	346	Moore, J.P., et al.	1971	A	4-400	Ni_3Fe:O1			Above specimen heated to 1350 K under 10^{-7} mmHg vacuum during experiment and subsequently cooled to room temp at a rate of about 5 deg/min; specimen considered to have high degree of local order but no long-range order.
41*	346	Moore, T.P., et al.	1971	A	767-602	Ni_3Fe:O2			Specimen cut from remaining half of ingot with composition being quite similar to above specimen; heat treatment consisted of heating to 1360 K under 10^{-7} mmHg vacuum and cooling to a soak temperature (767K) over 34-day period; cooling to soak temperature carried out such that no measurable (±0.1%) change in electrical resistivity occured during 24 hrs following 4 hr soak at a given temp; soaks applied at several temperatures below the order-disorder critical temperature of 771 K; soak times for the seven soak temperatures given here are 47, 28, 19, 25, 28, 12, and 21 days, respectively.
42*	346	Moore, T.P., et al.	1971	A	4-400				Above specimen measured following achievement of an essentially completely ordered state.
43	336	Gautier, F., and Loegel, B.	1972	A	4-60			39.8	Composition reported as 41 at.% Fe; alloy preparation reported by Cadeville and Loegel [358]; alloys prepared by melting 4N8 starting materials from Koch-light provenance in an induction furnace under argon atmosphere with the ingots subsequently annealed 1 day at 1323 K and quenched; crystalline structure at room temp is fcc as determined from x-ray measurements; data obtained from the expression $\rho = \rho_0 + 0.00019\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60K$) reported by authors.
44	336	Gautier, F., and Loegel, B.	1972	A	4-60			42.8	Composition reported as 44 at.% Fe; preparation and measurement similar to above specimen; data obtained from the expression $\rho = \rho_0 + 0.00022\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60K$) reported by authors.
45	336	Gautier, F., and Loegel, B.	1972	A	4-60			45.8	Composition reported as 47 at.% Fe; preparation and measurement similar to above specimen; data obtained from the expression $\rho = \rho_0 + 0.000265\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60K$) reported by authors.
46	336	Gautier, F., and Loegel, B.	1972	A	4-60			48.8	Composition reported as 50 at.% Fe; preparation and measurement similar to above specimen; data obtained from the expression $\rho = \rho_0 + 0.00037\ T^2$ (ρ in $\mu\Omega$cm, $T \leq 60K$) reported by authors.

* Not shown in figure.

TABLE 60. MEASUREMENT INFORMATION OF THE ELECTRICAL RESISTIVITY OF NICKEL + IRON ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Fe	Composition (continued), Specifications, and Remarks
47	327	Schwerer, F.C. and Conroy, J.W.	1971	A	4-297			0.48	Composition reported as 0.50 at.% Fe (premelt value); alloy prepared by arc-melting nickel and iron, each supplied by United Mineral and Chemical Corp., with nominal purity of 99.997%; ingot cold-rolled and machined/ground to cylinder 3.81 cm long x 0.25 cm diameter; specimen sealed in quartz capsule under prepurified nitrogen atmosphere and annealed at 1273 K for 1 wk; mass spectrographic analysis indicated impurity levels of starting materials and of alloy specimens were similar and with principal impurities being 20 ppm Cu and 0.003 wt.% C; residual resistivity of nickel standard of 0.013 $\mu\Omega$cm thought due to dissolved carbon; geometrical factor determined from mass, density and length measurement to ±0.2% accuracy; data scatter reduced by cycling specimen through longitudinal magnetic field of ~1 kOe prior to measurement at each temperature; data reported as residual resistivity and deviations from Matthiessen's rule in figure format; following a reading of the figures the total resistivity was recovered and is given here.
48	327	Schwerer, F.C. and Conroy, J.W.	1971	A	4-297			0.85	Composition reported as 0.89 at.% Fe (premelt value); similar to the above specimen.
49	327	Schwerer, F.C. and Conroy, J.W.	1971	A	4-297			1.14	Composition reported as 1.20 at.% Fe (premelt value); similar to the above specimen.
50	327	Schwerer, F.C. and Conroy, J.W.	1971	A	4-302			1.7	Composition reported at 1.8 at.% Fe (average over two specimens); similar to the above specimen.
51	327	Schwerer, F.C. and Conroy, J.W.	1971	A	4-300			3.66	Composition reported as 3.85 at.% Fe (premelt value); similar to above specimen.
52	350	Baum, B.A., Tyagunov, G.V., Gel'd, P.V., and Khasin, G.A.	1971	R	1560-1979		66.1		Composition reported as 65 at.% Ni; data reported in both solid and liquid states in figure format; $d\rho/dT = 0.0020$ $\mu\Omega$cm K^{-1} in liquid state; increasing temperature data.
53*	350	Baum, B.A., et al.	1971	R	1943-1481				Data show temperature hysterisis across melting range; above specimen measured at decreasing temperatures.
54	350	Baum, B.A., et al.	1971	R	1514-1995		85.6		Composition reported as 85 at.% Ni; data reported in both solid and liquid states; $d\rho/dT = 0.0032$ $\mu\Omega$cm K^{-1} in liquid state; increasing temperature data.
55*	350	Baum, B.A., et al.	1971	R	1953-1423				Data show temperature hysterisis across melting range; above specimen measured at decreasing temperature.

* Not shown in figure.

TABLE 60. MEASUREMENT INFORMATION OF THE ELECTRICAL RESISTIVITY OF NICKEL + IRON ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Fe	Composition (continued), Specifications, and Remarks
56	330	Shirakawa, Y.	1939	B	78-1123	No. 10		39.76	Alloys prepared from electrolytic iron and nickel supplied by Nippon-Denkai-Saitetsusho and by Monson and Co. respectively; chemical analysis of starting materials include, for iron: 0.05% Si, 0.05% P, 0.04% C, 0.02% Co, 0.02% Mn, 0.01% Al, 0.003% S_2 and for nickel: 0.02% Fe, 0.01% C, 0.003% S, 0.002% Si, 0.001% P, and 0.001% Mn; weighed amounts were mixed and then melted under hydrogen atm. in an alumina crucible within a Tamman furnace; wire formed by drawing molten alloy up into a silica capillary which was subsequently carefully broken; specimen annealed at 1273 K for 1 hr under vacuum and cooled slowly with length oriented along east-west direction; specimen dimensions were 6.22 cm length x 0.0320 cm dia; nickel lead wire soldered to each end of specimen with pure silver; specimen plus leads annealed again at 1123 K under high vacuum for 1 hr and slowly cooled; specimen orientation during measurement always east-west; magnetoresistance in longitudinal fields up to 1.6 kOe also measured; resistivity measurement technique is of two-probe type; data reported in tabular form.
57	330	Shirakawa, Y.	1939	B	78-1123	No. 11		29.85	Similar to above specimen except dimensions were 7.02 cm length x 0.0220 cm diameter.
58	330	Shirakawa, Y.	1939	B	78-1123	No. 12		19.93	Similar to above specimen except dimensions were 6.92 cm length x 0.0239 cm diameter.
59	330	Shirakawa, Y.	1939	B	78-1123	No. 13		16.15	Similar to above specimen except dimensions were 2.60 cm length x 0.0416 cm diameter.
60	330	Shirakawa, Y.	1939	B	78-1123	No. 14		10.21	Similar to above specimen except dimensions were 3.62 cm length x 0.0355 cm diameter.
61	338	Larikov, L.N., Usov, Yu.V., and Boychuk, I.N.	1977		4-1275		50.84		Measurement included both increasing and decreasing temperatures; data reported in figure format.
62	348	Szentirmay, Zs.	1976	A	143-340	FN-O	58.2		Composition reported for material designated FN-O includes: 0.01 wt.% Si, <0.01 wt.% Mn, 0.0174 wt.% O, 0.0044 wt.% C, and 0.0008 wt.% S; alloys made at Csepel Metalworks, Budapest, from 4N nickel and 3.5 N iron starting materials by induction melting under vacuum, remelting in an electron-beam furnace, and lastly cold-rolling with 95% reduction; compositions determined after final rolling; specimens cut parallel to rolling direction into dimensions of 43 x 5 x 0.22 mm^3 and subjected to a heat treatment sequence consisting of heating to 1273 K for 3 hrs, annealing at 973 K for 1 hr in vacuo, and oil-quenching; an annealing investigation was also carried out involving an anneal at 973K for 1 hr ($T>T_C$) and thereafter at 703 K for 3 hr ($T>T$ ordering), and lastly furnace cooled at rate of 100 deg hr^{-1}; three specimens from each alloy composition were annealed, one ea with zero magnetic field, or with saturation magnetic field applied either parallel or perpendicular to rolling direction; specimen strip mounted between two copper blocks which in turn were enclosed within a cryostat thermostated by circulating liquid nitrogen vapors for temps below room temp or by water for above; specimen temp cooling rate varied between 0.5 to 1.5 deg/min; uncertainty estimated to be ±0.5%; quenched specimen data.

TABLE 60. MEASUREMENT INFORMATION OF ELECTRICAL RESISTIVITY OF NICKEL + IRON ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ni	Fe	Composition (continued), Specifications, and Remarks
63	348	Szentirmay, Zs.	1976	A	163-351	FN-Li	64.5		Composition reported includes 0.01 wt.% Si, <0.01 wt.% Mn, 0.0008 wt.% O, 0.0052 wt.% C, 0.0005 wt.% S, and 0.0022 wt.% Li; similar in other respects to above specimen.
64*	329	Schwerer, F.C. and Cuddy, L.J.	1970	A	4.2-942			0.52	Composition reported as 0.55 at.% Fe; alloys prepared from high-purity (99.997% nominal as supplied by United Mineral and Chemical Corp., N.Y.) by arc-melting under argon atmosphere and cold-rolling to 60% reduction; alloy sealed in quartz capsule under nitrogen atmosphere and annealed at 1273 K for 1 wk; specimen machined as 3.8 cm x 0.25 cm diameter cylinder and reannealed for 2 hr at 1073 K; solute concentration determined by chemical analysis; current and potential leads of nickel spot welded with gauge length measured by traveling microscope; average cross-section determined from length, density, and mass; largest sources of error thought to be geometrical factors for which uncertainties are < 0.2%; errors in solute resistivity certainly less than ±0.5% of iron standard; high temperature measurements involved mounting specimen and nickel standard (ρ_0 % 0.024 μΩcm) within noninductively wound furnace in thermal proximity of each other and thermocouple well; specimen environment He-2% H_2 flowing atmosphere; temperature monitored with Pt/Pt-10% Rh thermocouple; electric current of 0.5 amp stabilized to 1:10^5 applied; temperature changed at rate of 1 deg min^{-1}; voltages measured with Keithley 140 amplifier and digital voltmeter; complete set of measurements (including specimen, standard, and reversals) could be made within temperature change of ≤ 0.2 deg; data reported as solute resistivity (= $\rho_{alloy} - \rho_{standard}$) in figure format.
65*	329	Schwerer, F.C. and Cuddy, L.J.	1970	A	4.2-906			1.01	Composition reported as 1.06 at.% Fe; preparation and measurement similar to above specimen.

* Not shown in figure.

TABLE 61 EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF NICKEL + IRON ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

T	ρ
DATA SET 1	
273	14.3
293	15.5
373	20.0
473	26.4
573	35.0
673	45.0
773	55.2
873	62.8
973	68.3
DATA SET 2	
4.18	3.78
80.5	4.60
292.7	13.22
DATA SET 3	
4.2	0.307
11.4	0.319*
13.3	0.324*
14.5	0.326*
20.1	0.340*
22.3	0.348*
27.1	0.370*
31.0	0.390*
36.0	0.421*
41.7	0.465*
53.0	0.592*
63.3	0.743*
70.3	0.850*
81.6	1.07*
89.2	1.22
DATA SET 4	
4.2	0.713
12.5	0.723*
14.5	0.731*
16.3	0.737*
22.0	0.762*
30.5	0.815*
35.4	0.868*
40.5	0.916*
43.6	0.964*
52.9	1.12*
65.2	1.31*

T	ρ
DATA SET 4 (cont.)	
70.2	1.46*
77.9	1.64*
89.1	1.92*
261	7.42*
273	7.99
DATA SET 5	
4.2	1.80
14.1	1.81*
19.0	1.84*
21.7	1.85*
24.1	1.86*
29.6	1.89*
33.9	1.94*
39.3	2.01*
44.3	2.08*
55.3	2.27*
59.6	2.34*
70.2	2.57*
76.8	2.79*
86.5	3.03*
268	9.45*
273	9.84
DATA SET 6	
14	4.251
20	4.418
64	4.798
77	5.006
273	11.581
DATA SET 7	
77	12.8
293	17.2
DATA SET 8*	
293	15.8

Time(hrs)	ρ
DATA SET 9* (T = 783 K)	
0	61.0
25	61.0
48	61.0
DATA SET 10 (T = 773 K)	
0	59.2*
26	59.2*
50	59.2
DATA SET 11 (T = 763 K)	
0	58.0*
21	56.3*
43	55.4*
78	53.5*
94	52.8*
125	51.7*
164	51.2
DATA SET 12 (T = 753 K)	
0	56.7*
16	55.2*
42	53.6*
67	51.7*
113	50.7*
164	49.6
DATA SET 13 (T = 722 K)	
0	52.0*
27	49.0*
46	47.9*
94	46.3*
117	45.8

T	ρ
DATA SET 14	
662	45.1
696	49.0
727	52.9
758	57.4
775	59.7*
789	62.0*
828	68.0
DATA SET 15*	
675	42.2
709	47.5
727	50.2
741	53.2
771	59.0
783	61.4
803	64.2
DATA SET 16*	
691	39.3
707	41.4
717	43.3
726	44.7
735	46.4
750	50.8
759	55.1
775	59.8
779	60.5
796	63.1
809	65.1
814	66.0
DATA SET 17*	
666	35.0
678	36.3
686	37.4
696	38.6
706	39.8
718	41.7
726	42.9
735	44.5
744	46.6
753	48.3
762	50.6
765	54.7

T	ρ
DATA SET 17 (cont.)*	
769	57.9
783	61.2
DATA SET 18	
667	59.9
683	62.6
703	65.6
735	70.7
771	76.9
806	83.4
DATA SET 19*	
684	59.1
712	64.2
724	66.4
746	70.8
754	73.2
770	76.3
787	79.8
804	83.0
DATA SET 20*	
682	53.7
695	56.0
710	58.6
715	59.8
725	61.6
736	64.4
740	65.6
750	68.8
760	74.1
767	76.0
782	78.8
794	81.3
799	82.1
DATA SET 21*	
663	49.2
696	53.7
730	58.5
762	63.2
801	70.0

T	ρ
DATA SET 22*	
659	47.3
691	51.8
700	52.9
719	56.3
748	61.1
778	66.1
798	69.7
DATA SET 23*	
676	48.6
691	51.2
700	52.6
707	53.9
716	55.2
730	57.6
739	58.9
752	61.4
756	62.0
764	63.5
772	64.8
784	66.9
801	70.0
DATA SET 24*	
671	47.1
682	48.9
691	50.2
701	52.0
708	53.5
720	55.6
736	58.6
754	61.5
761	62.6
769	64.2
775	65.1
DATA SET 25*	
683	94.5
701	97.3
707	97.8
730	101.2
734	101.9
749	104.0
761	105.5

* Not shown in figure.

TABLE 61. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF NICKEL + IRON ALLOYS (Temperature Dependence) (continued)

DATA SET 25 (cont.)*

T	ρ
771	107.2
783	108.4
822	110.6
831	111.6

DATA SET 26*

T	ρ
704	96.3
718	98.6
730	100.7
749	103.4
765	105.9
771	106.5
774	107.0
780	108.1
803	109.8
832	111.1
846	111.6
863	112.1

DATA SET 27*

T	ρ
685	92.8
691	93.8
700	95.5
705	96.2
725	99.8
739	102.0
748	103.2
757	104.7
769	106.3
774	107.0
779	107.7
783	108.3
788	108.9
797	109.5
801	109.7

DATA SET 28

T	ρ
631	39.4
660	42.6
705	48.0
723	50.2
738	52.1
750	54.1
756	55.6
761	56.3*
765	57.1
769	58.1*
772	59.1*

DATA SET 28 (cont.)

T	ρ
775	60.1*
777	61.0*
779	62.4
782	64.2
784	64.7*
786	65.1*
789	65.5*
792	66.1
795	66.5*
798	67.1*
802	67.6*
807	68.6*
810	69.5*
814	70.2*
819	70.9
823	71.9*
828	72.5*
833	73.6
837	74.3*
847	76.2
849	76.6*
850	76.7*
852	77.2*
853	77.4*
855	77.8*
855	77.9*
857	78.2*
858	78.4*
858	78.6
860	78.8*
861	79.0*
863	79.1*
863	79.2*
865	79.3*
865	79.4*
867	79.5*
868	79.7*
869	79.7*
871	79.8*
871	79.9*
874	80.0*
877	80.4

DATA SET 29

T	ρ
703	53.2
712	54.6
722	56.2
734	57.7
749	59.9
758	61.1

DATA SET 29 (cont.)

T	ρ
768	62.5
776	63.7*
782	64.8*
788	65.7*
794	66.6*
798	67.3*
800	67.7*
801	67.8*
807	68.6*
810	69.5*
814	70.2*
819	70.9*
823	71.7*
828	72.5*
833	73.6*
837	74.3*
847	76.2*
849	76.6*
850	76.7*
852	77.2*
853	77.4*
855	77.8*
855	77.9*
857	78.2*
858	78.4*
858	78.5*
858	78.6*
860	78.8*
861	79.0*
863	79.1*
865	79.3*
865	79.4*
867	79.5*
868	79.7*
869	79.7*
871	79.9*
874	80.0*
877	80.4

DATA SET 30*

T	ρ
298	19.9

DATA SET 31

T	ρ
298	43.2

DATA SET 32

T	ρ
4.0	17.4
19.65	17.6
75.75	19.5

DATA SET 32 (cont.)

T	ρ
192.4	29.2
273	39.2

DATA SET 33

T	ρ
4.0	11.4
19.65	11.5
75.75	12.2
192.4	16.3
273	20.6

DATA SET 34

T	ρ
1702	135.4
1800	137.7
1873	139.4
1898	140.0

DATA SET 35*

T	ρ
1707	120.8
1800	123.2
1873	125.1
1898	125.8

DATA SET 36

T	ρ
1710	118.4
1800	121.9
1873	124.8
1898	125.8

DATA SET 37

T	ρ
4.2	15.1
30.9	15.49
33.4	15.48
37.5	15.63
42.0	15.73
47.6	15.88
52.7	16.08
57.8	16.33
61.3	16.43
65.4	16.63
69.9	16.78
74.5	17.08
78.0	17.23
83.6	17.58
89.7	17.88
94.8	18.23
100.4	18.58

DATA SET 37 (cont.)

T	ρ
105.4	19.03
111.0	19.43
117.1	19.83
122.2	20.13

DATA SET 38

T	ρ
4.2	4.6
30.9	4.61
33.9	4.71
37.0	4.79
41.0	4.76
47.1	4.76
52.2	4.86
57.2	4.96
65.8	5.00
67.9	5.10
70.9	5.15
76.0	5.30
80.0	5.45
85.1	5.50
90.2	5.60
94.7	5.70
97.8	5.90
104.9	6.10
113.5	6.35
120.6	6.64

DATA SET 39

T	ρ
4.2	4.25
80	5.05
100	5.55
120	6.18
140	6.90
160	7.70
180	8.65
200	9.64
220	10.78
240	11.99
260	13.35
280	14.75
300	16.20
320	17.75
340	19.44
360	21.15
380	22.95
400	24.77

DATA SET 40

T	ρ
4.2	4.00
80	4.77
100	5.24
120	5.80
140	6.46
160	7.19
180	8.03
200	9.00
220	10.07*
240	11.22
260	12.48
280	13.78
300	15.13
320	16.56
340	18.08
360	19.69
380	21.45
400	23.17

DATA SET 41*

T	ρ
767	57.66
755	54.35
735	49.98
713	45.75
673	40.21
645	36.78
602	32.19

DATA SET 42*

T	ρ
4.2	2.81
80	3.37
100	3.70
120	4.10
140	4.52
160	5.01
180	5.54
200	6.12
220	6.76
240	7.46
260	8.22
280	9.07
300	9.98
320	10.95
340	11.99
360	13.10
380	14.27
400	15.53

* Not shown in figure.

TABLE 61. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF NICKEL + IRON ALLOYS (Temperature Dependence) (continued)

DATA SET 43

T	ρ
4.2	6.1
10	6.07
20	6.13
30	6.22
40	6.35
50	6.53
60	6.73

DATA SET 44

T	ρ
4.2	6.8
10	6.80
20	6.87
30	6.98
40	7.13
50	7.33
60	7.57

DATA SET 45

T	ρ
4.2	7.7
10	7.78
20	7.86
30	7.99
40	8.17
50	8.41
60	8.70

DATA SET 46

T	ρ
4.2	8.8
10	8.86
20	8.95
30	9.11
40	9.33
50	9.61
60	9.95

DATA SET 47

T	ρ
4.2	0.202
15	0.214
19	0.225
24	0.240
29	0.260
34	0.289
42	0.349
49	0.415

DATA SET 47 (cont.)

T	ρ
59	0.540
70	0.708
80	0.912
92	1.16
102	1.39
118	1.78
134	2.21
144	2.48
160	2.91
182	3.64
202	4.21
240	5.45
261	6.20
278	6.81
297	7.54

DATA SET 48

T	ρ
4.2	0.349
5	0.351
11	0.359
16	0.372
19	0.388
27	0.436
36	0.529
43	0.604
53	0.730
65	0.924
77	1.13
91	1.44
101	1.68
122	2.21
143	2.78
166	3.45
190	4.16
202	4.53
233	5.56
249	6.14
274	7.04
297	7.91

DATA SET 49

T	ρ
4.2	0.473
24	0.530
31	0.575
36	0.615
42	0.687

DATA SET 49 (cont.)

T	ρ
51	0.792
61	0.957
69	1.11
80	1.34
90	1.59
101	1.86
114	2.20
127	2.58
142	2.99
158	3.45
176	3.98
192	4.51
202	4.83
232	5.82
254	6.61
275	7.36
297	8.22

DATA SET 50

T	ρ
4.2	0.667
18	0.699
27	0.737
34	0.781
48	0.958
62	1.21
81	1.58
91	1.85
101	2.13
113	2.47
126	2.84
143	3.36
165	4.01
184	4.62
203	5.23
222	5.89
237	6.41
261	7.27
283	8.12
302	8.86

DATA SET 51

T	ρ
4.2	1.33
9	1.33
21	1.37
29	1.40
39	1.50

DATA SET 51 (cont.)

T	ρ
53	1.72
69	2.07
84	2.43
100	2.93
119	3.53
139	4.15
157	4.76
175	5.36
190	5.92
202	6.34
221	7.05
249	8.07
274	9.09
300	10.17

DATA SET 52

T	ρ
1560	122.2
1599	124.8
1640	125.5
1694	126.9
1723	136.9*
1785	138.4*
1826	137.1*
1863	137.2*
1893	138.1*
1958	138.0
1979	138.1

DATA SET 53*

T	ρ
1943	137.7
1910	137.4
1839	137.3
1823	138.9
1775	137.1
1739	137.7
1701	137.0
1669	138.0
1643	136.8
1605	135.7
1555	135.0
1522	123.9
1504	122.4
1481	120.9

DATA SET 54

T	ρ
1514	94.1
1552	95.8
1595	97.5
1639	98.7
1688	100.3
1737	105.5
1760	106.0
1794	106.0
1819	106.3*
1864	106.3
1918	106.2
1965	106.2
1995	107.0

DATA SET 55*

T	ρ
1953	105.3
1903	106.2
1864	105.0
1828	105.7
1773	106.5
1723	106.5
1672	106.5
1620	105.3
1561	101.9
1526	101.9
1467	92.7
1444	91.6
1423	90.8

DATA SET 56

T	ρ
78	8.03
178	12.4
273	19.7
284	21.1
399	34.5
475	45.2
571	58.2
672	71.4
772	87.4
843	99.9
864	103.1*
873	104.1*
883	104.9
923	106.6
1016	108.9
1123	110.9

DATA SET 57

T	ρ
78	5.85
178	8.99
228	11.4
273	15.3
283	15.9*
315	16.6
371	23.0
472	33.5
572	45.0
682	57.9
775	72.0
844	83.5
865	87.5*
874	69.4*
884	91.2*
893	92.2
903	93.1*
923	94.1
974	95.9
1024	97.0*
1074	97.9
1123	98.9

DATA SET 58

T	ρ
78	5.69
178	8.51*
273	13.6
319	17.3*
372	21.1*
465	29.0
551	38.8
680	50.1
782	64.0*
825	71.7*
843	75.0*
853	77.3*
863	78.3*
873	79.1*
923	81.6
1023	84.0
1123	86.4

DATA SET 59

T	ρ
78	9.48
178	10.01
273	13.9

* Not shown in figure.

TABLE 61. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF NICKEL + IRON ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 59 (cont.)	
372	18.8
474	26.4*
573	34.9*
672	45.0*
773	58.0*
803	63.4
815	65.9*
824	67.4*
833	67.9*
843	68.8
873	70.2
921	72.1
1023	75.8
1123	78.4
DATA SET 60	
78	5.11
178	8.11
273	12.3
290	12.8*
319	14.4
385	17.9
504	25.4
629	36.0
723	46.3*
752	50.4*
763	52.4*
768	53.6*
773	53.9
792	55.0*
823	56.1*
873	58.1
923	60.0
973	61.6
1023	63.2
1073	64.9*
1123	66.5
DATA SET 61	
4.2	9.1
89	11
313	30
358	36
417	44
440	47*

T	ρ
DATA SET 61 (cont.)	
462	51
492	56*
522	59
552	62*
574	68*
596	71
626	74*
656	78
686	82*
723	88
753	94*
775	97*
812	100
842	103*
902	106*
969	107
1029	110*
1096	112*
1155	112
1222	113*
1275	113
1252	113*
1193	113*
1125	112*
1066	112*
1006	109*
939	107*
880	106*
820	104*
775	103*
730	98*
678	91*
648	86*
589	77*
552	71*
507	65*
455	57*
410	51*
395	41*
335	32*
DATA SET 62	
143	9.8
154	10.4*
163	11.1*
173	11.7*

T	ρ
DATA SET 62 (cont.)	
182	12.4
191	13.2*
203	13.9*
212	14.8*
222	15.7
232	16.7*
242	17.5*
251	18.2
261	19.4*
272	20.8*
281	21.4*
291	22.5
300	23.7*
310	24.7*
321	26.2
330	27.2*
340	28.6
DATA SET 63	
163	8.9
173	9.5*
183	10.2*
193	10.8*
204	11.5
214	12.2*
223	12.9*
233	13.6*
243	14.4
251	15.2*
262	15.8*
272	16.7*
282	17.5
292	18.4*
301	19.5*
312	20.3*
323	21.7
331	22.6*
340	23.7
351	25.0

T	ρ
DATA SET 64*†	
4.2	0.23
300	0.51
331	0.50
372	0.49
407	0.47
445	0.45
480	0.41
509	0.39
544	0.34
576	0.33
603	0.30
632	0.10
637	0.13
640	0.36
649	0.53
686	0.61
701	0.65
754	0.66
806	0.68
847	0.69
885	0.70
942	0.72
DATA SET 65*†	
4.2	0.51
301	1.23
342	1.19
380	1.17
429	1.19
478	1.15
543	1.15
601	1.03
619	0.87
630	0.85
636	1.22
642	1.48
659	1.76
682	1.82
726	1.90
781	1.95
834	2.04
906	2.14

* Not shown in figure.
† Solute resistivity.

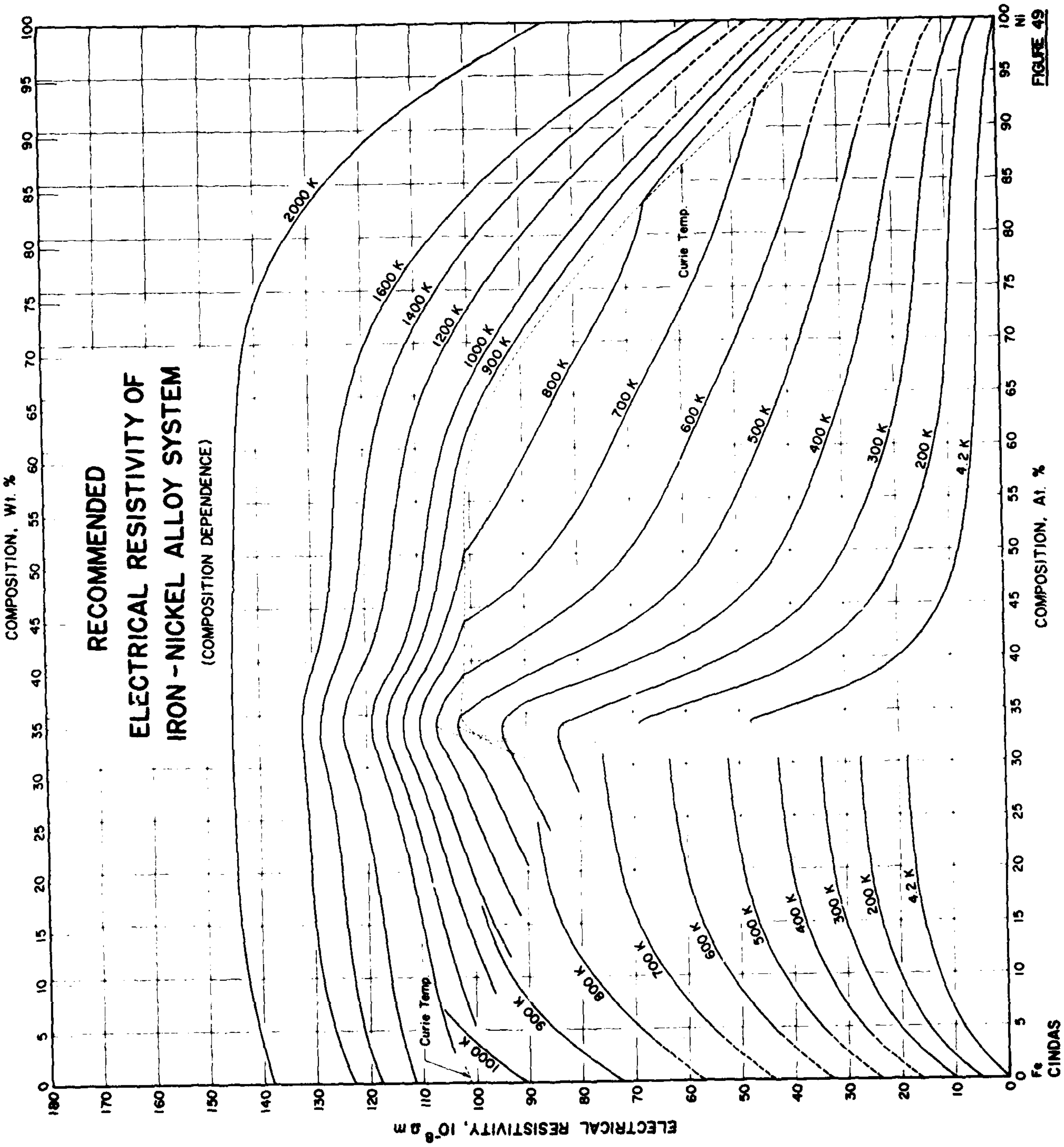


FIGURE 49

CINDAS

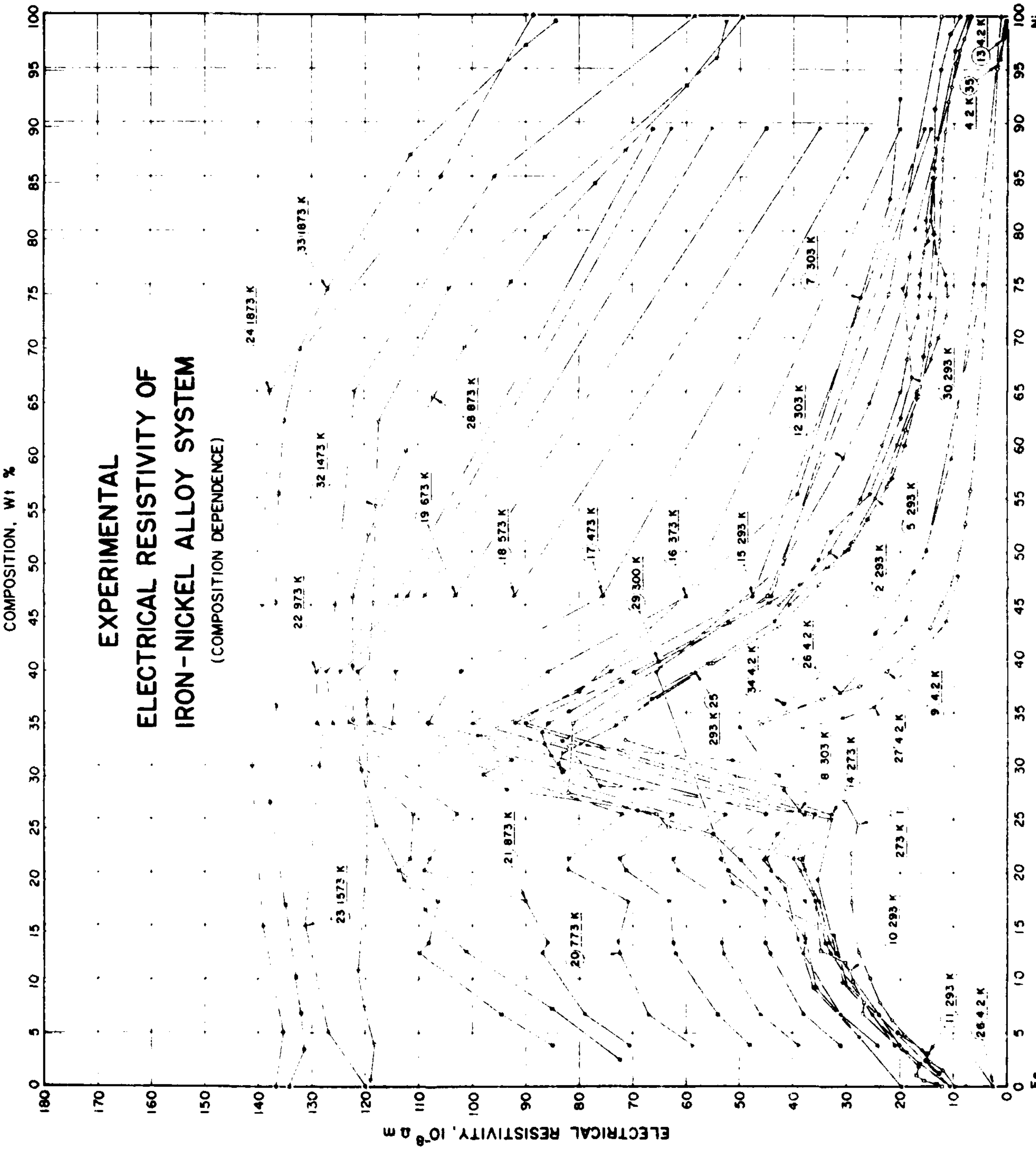

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
IRON-NICKEL ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION, Wt %
COMPOSITION, At %
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
Fe
Ni
CINDAS
24 1873 K
33 1873 K
23 1573 K
32 1473 K
22 973 K
21 873 K
28 873 K
20 773 K
19 673 K
18 573 K
17 473 K
16 373 K
29 300 K
15 293 K
12 303 K
7 303 K
8 303 K
14 273 K
273 K
10 293 K
11 293 K
2 293 K
5 293 K
30 293 K
26 4.2 K
34 4.2 K
27 4.2 K
9 4.2 K
4.2 K (35)
(13) 4.2 K

FIGURE 50

TABLE 62. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM (Composition Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Ni)	Composition (weight percent), Specifications, and Remarks
1	367	Broniewski, W. and Smolinski, J.	1933		273	0-100	Alloys prepared from weighed amounts of electrolytic iron and nickel by melting under vacuum in 5 mm silica tube within high frequency furnace; specimen annealed 100 hrs at 1223 K in vacuum and subsequently slow-cooled to room temp in 24 hrs; photomicrography indicated mixed phases occurring between the 28 and 32 percent nickel compositions; data presented as a smoothed curve of electrical conductivity in figure format.
2	347	Wakelin, R.J. and Yates, E.L.	1953	A	293	45-85	Alloys prepared from 99.94% pure nickel and iron containing 0.7% oxygen by melting weighed amounts in pure alumina crucibles under vacuum within a high-frequency furnace; rapid melting under pressure too low for an electrodeless discharge to occur resulted in minimal impurity uptake as evidenced by chemical analysis typically showing < 0.2% total impurity content; alloys hot-forged and homogenized at 1473 for 18 hrs; subsequent photomicrographs showed uniform composition throughout; specimens machined to dimensions of 10 cm x 4 cm x 1 mm with cross-section uniform to ±0.02 mm; reproducibility of measurements indicated ±0.5% uncertainty; specimen chamber temperature controlled to ±0.5 deg; specimen disordered by heating to 973 K and quenching.
3*	347	Wakelin, R.J. and Yates, E.L.	1953	A	293	45-85	Similar to above specimens except cooling rate from 973 K was 100 deg hr^{-1}.
4*	347	Wakelin, R.J. and Yates, E.L.	1953	A	293	45-85	Similar to above specimens except cooling rate was 1.3 deg hr^{-1}.
5	347	Wakelin, R.J. and Yates, E.L.	1953	A	293	45-85	Similar to above specimens except cooling rate was 0.28 deg hr^{-1}.
6*	347	Wakelin, R.J. and Yates, E.L.	1953	A	293	75	Similar to above specimens except cooling rate was 0.09 deg hr^{-1}.
7	354	Honda, K.	1918		303	0-92	Composition of commercial grade starting materials was for iron: 0.31% Mn, 0.258% Cu, 0.11% Si, 0.09% C, 0.030% P, and 0.028% S, and for nickel: 4.20% Cu, 1.25% Fe, 0.35% Mn, 0.29% C, 0.25% Co, 0.15% Si, and 0.017% Si; alloys prepared by melting weighed amounts in a porcelain crucible within a Tamman electric furnace; procedure repeated if lengthwise microscopic examination revealed inhomogeneities; alloys forged, annealed, and filed into rod form of dimension 20 cm x 5 cm; three alloy samples chosen for nickel content determination which subsequently confirmed initial weight readings; specimen annealed at 1173 K and cooled to room temperature before measurement; data reported in tabular format.
8	354	Honda, K.	1918		303	0-33	Similar to above specimens except cooled in liquid air prior to measurement.
9	358	Cadeville, M.C. and Loegel, B.	1973	A	4.2	34-98	Alloys prepared by melting nickel and iron 4N8 from Koch-light provenance in an induction furnace under argon atmosphere; specimens subsequently annealed at 1323 K for 1 day and quenched; room temperature x-ray measurements indicate only fcc structure being present.
10	353	Burgess, C.F. and Aston, J.	1911		297	0.27-75.06	Alloys prepared "with every precaution to avoid contamination"; composition determined from chemical analysis; bars 1 cm in diameter were quenched from 1173K; knife edge potential probes held in place by spring clips and spaced 7.854 cm apart which makes the electrical resistivity numerically equal to the measured electrical resistance; data presented in tabular form and carried units of "microohms/cm^3"; electrical measurements performed using a voltmeter-ammeter method to facilitate an extensive measurement program, admittedly less accurate than a bridge technique.
11	62	Gulyaev, A.P. and Trusova, E.F.	1950		293	1.2-5.0	Review article data reported in tabular format; temperature presumably a nominal room temperature.

* Not shown in figure.

TABLE 62. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Ni)	Composition (weight percent), Specifications, and Remarks
12	355	Bridgman, P.W.	1928	A	303	0-100	Alloys kindly given by McKechon of Bell Telephone Laboratories; composition checks indicate actual contents are within ±0.5% of nominal composition; alloys in wire form having been hard drawn to 0.25 mm diameter; specimens given an anneal at 1273 K for 1 hr under vacuum and cooled slowly (several hrs) to room temperature; effects of pressure upon electrical resistance also reported; data presented in table and figure format giving electrical resistivity and temperature and pressure coefficients; uncertainty due largely to wire diameter measurement and estimated to be ±1% to ±2%.
13	327	Schwerer, F.C. and Conroy, J.W.	1971	A	4.2	96-100	Alloys prepared by arc-melting nickel and iron, each supplied by United Mineral and Chemical Corp. and of nominal purity 99.997%; ingots cold-rolled and machined to cylinders 3.81 cm long x 0.25 cm diameter; specimens sealed in quartz capsules under prepurified nitrogen atmospheres and annealed at 1273 K for 1 wk; mass spectrographic analyses indicated that impurity levels were similar for starting materials and alloy specimens; principal metallic impurities were Cu at 0.0020 wt.% level and C at 0.003 wt.%; compositions given here are premelt values; residual resistivity of nickel standard thought due to dissolved carbon; geometrical factors determined from density, mass, and length measurements to about ±0.2%; data scatter reduced by cycling specimens through longitudinal magnetic fields of ~1kOe at each temperature prior to measurement; uncertainty thought to be about ±0.002 μΩcm.
14	332	Ingersoll, L.R.	1920	A	273	3.8-89.5	Composition includes an estimated < 0.10% C; alloys prepared from doubly electrodeposited iron of 99.97% purity and electrolytic nickel of high purity; ingots formed from weighed amounts by melting in a magnesia crucible heated within a resistor furnace and subsequently forging and machining into 1 cm bars; a measuring current of some 7.5 amps was applied; temperatures were measured with a copper-constantan thermocouple; smoothed values were reported in figure format; data apparently taken with increasing temperature only; possible transformation to austenite at highest temperatures for the ≤ 30 at.% Ni alloys was not discussed.
15	332	Ingersoll, L.R.	1920	A	293	3.8-89.5	The above specimens.
16	332	Ingersoll, L.R.	1920	A	373	3.8-89.5	The above specimens.
17	332	Ingersoll, L.R.	1920	A	473	3.8-89.5	The above specimens.
18	332	Ingersoll, L.R.	1920	A	573	3.8-89.5	The above specimens.
19	332	Ingersoll, L.R.	1920	A	673	3.8-89.5	The above specimens.
20	332	Ingersoll, L.R.	1920	A	773	3.8-89.5	The above specimens.
21	332	Ingersoll, L.R.	1920	A	873	3.8-89.5	The above specimens.
22	332	Ingersoll, L.R.	1920	A	973	3.8-89.5	The above specimens.
23	350	Baum, B.A., Tyagunov, G.V., Gel'd, P.V., and Khasin, G.A.	1971	R	1573	5-100	Specimens in solid state.
24	350	Baum, B.A., et al.	1971	R	1873	0-100	Specimens in liquid state.
25	341	Kalinin, V.M., Danilov, M.A., Komarova, L.K., and Tseytlin, A.M.	1973		293	29.5-38.7	Alloy specimens prepared as cylinders with dimensions 150 mm long x 12 mm diameter; specimens annealed at 1173 K for 2 hrs under 10^{-4} mmHg vacuum prior to measurement; temperature presumably a nominal room temperature.

TABLE 62. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Ni)	Composition (weight percent), Specifications, and Remarks
26	339	Kondorskii, E.I., and Sedov, V.L.	1960		4.2	0-100	Specimen rods of dimension 112 mm long x 5.9 mm diameter fabricated from technically pure starting materials; prior to measurement specimens vacuum annealed at 1273 K for 8 hrs and furnace cooled; pressure dependence of residual resistance also reported in hydrostatic pressure range; data presented in tabular form.
27	338	Larikov, L.N., Usov, Yu.V., and Boychuk, I.N.	1977		4.2	34.54-49.59	Compositions reported as 35.68, 36.9, 37.64, 44.86, 50.84 wt.%; data reported in figure format.
28	342	Window, B.	1973		873	2.5-99.9	No experimental details reported; smoothed data presented in figure format.
29	342	Window, B.	1973		300	29.2-100	Similar to above specimen.
30	340	Jellinghaus, W., and de Andrés, M.P.	1960	B	293	0-100	Alloys prepared from carbonyl iron and carbonyl nickel powder; composition of starting materials included ≤0.01% each C, Si, and Mn; ingot cold worked to 0.3 mm thickness and subsequently annealed under hydrogen atmosphere at 1423 K for 2 hrs; specimen cut to 150 mm length x 15 mm width; instrumentation incorporated a Thomson bridge and a standard resistance; data presented in tabular form.
31*	340	Jellinghaus, W. and de Andrés, M.P.	1960	B	293	0-100	Selected specimens from those above subjected to 80%-90% cold-work.
32	351	Epin, V.N., Baum, B.A., and Tyagunov, G.V.	1977	R	1473	0-100	No experimental details reported; specimens in solid state; data presented in figure format.
33	351	Epin, V.N., et al.	1977	R	1873	0-100	No experimental details reported; specimens in liquid state; data presented in figure format along with $d\rho/dT$ for liquid state and $\rho_{liquid}/\rho_{solid}$ for these same specimens.
34	335	Armstrong, B.E. and Fletcher, R.	1972	A	4.2	35.8-75.0	Alloys of commercial grade (with exception of 75 at.% Ni) and supplied by Henry Wiggin and Co., Hereford, England, in form of cold-rolled rods subsequently measured in as-received condition; 75 at.% Ni alloy prepared from 99.9% pure starting materials and subsequently heat-treated to 1273 K for 1 hr and cooled to 873 K at 100 deg hr^{-1} followed by a hold at 873 K for 8 hrs and water quenching; data scatter at 0.2% level while overall uncertainty estimated to be ±2%; data presented in figure format.
35	326	Farrell, T. and Greig, D.	1968	A	4.2	95.4-99.2	Alloys prepared by chill-casting under vacuum; iron content obtained from x-ray fluorescence measurement upon the two more dilute alloys and from residual resistivity for the other; geometrical factor determined to better than ±0.6% from length, density, and mass measurements; overall uncertainty estimated to be no more than ±1%; data presented in tabular form.

* Not shown in figure.

TABLE 62. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Ni)	Composition (weight percent), Specifications, and Remarks
36*	325	Fert, A. and Campbell, I.A.	1976	A	4.2	1, 2, 97-100	Alloys prepared at the CEN, Grenoble, in a levitation furnace from base metals obtained by zone melting (RRR = 700 and 25 for Ni and Fe respectively); alloys drawn into wires of 1 mm diameter and subsequently annealed at 1173 K for the nickel based alloys or 1073 K for the iron based alloys; absence of precipitates checked by micrography; most alloys analyzed by calorimetry or atomic absorption spectroscopy; resistivity measred between 1.3 K and 77 K and at several temperatures between 77 K and 300 K; accuracy generally limited (except for less concentrated alloys) by current stability of $\pm 2 \times 10^{-5}$; temperature in helium range measured with a germanium resistor with an accuracy of ± 0.1 deg; data presented in tabular form except for the nickel base alloys for which residual resistivities were recovered by reading compositions from a figure and combined with a tabulated ρ_0/at.% Fe value.
37*	325	Fert, A. and Campbell, I.A.	1976	A	24	97-100	Specimens same as the above; total electrical resistivities recovered from residual resistivities above combined with temperature dependent values at 24 K as read from a figure.

* Not shown in figure.

TABLE 63. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM (Composition Dependence)

[Composition, C, a/o Ni; Electrical Resistivity, ρ, 10^{-8} Ωm]

DATA SET 1 (T = 273 K)

C	ρ
0.0	9
1.5	11.9
2.3	14.3
3.4	15.9
4.8	19.1
6.2	21.4
7.8	23.7
10.1	25.6
12.5	27.7
17.2	29.1
21.8	29.1
24.5	27.8
26.7	30.2
29.0	50.5
32.4	71.4
34.5	71.4
39.6	54.9
43.0	42.6
46.9	35.3
51.0	28.7
56.1	22.4
61.4	19.0
64.5	16.5
69.4	14.4
72.7	13.4
79.1	12.6
82.7	12.3
86.7	12.1
89.2	11.6
92.0	11.0
93.4	10.4
95.6	9.7
96.8	8.9
97.9	8.0
100.0	6.7

DATA SET 2 (T = 293 K)

C	ρ
45	42.6
50	33.1
55	27.4
60	23.3
65	20.0
68	18.8
70	18.1
72	16.7
74	16.5
75	16.4
76	16.2
78	15.5
80	15.0
81	15.1
85	14.0

DATA SET 3* (T = 293 K)

C	ρ
45	41.4
50	31.6
55	25.4
60	21.3
65	18.2
68	16.9
70	16.3
72	15.3
74	15.5
75	15.0
76	15.0
78	14.8
80	14.2
81	14.4
85	13.6

DATA SET 4* (T = 293 K)

C	ρ
45	40.7
50	30.4
55	24.6
60	20.6
65	17.2
68	15.7
70	14.4
72	13.0
74	13.0
75	13.0
76	13.3
78	13.8
80	13.7
81	14.2
85	13.5

DATA SET 5 (T = 293 K)

C	ρ
45	40.6
50	30.3
55	24.6
60	20.5
65	16.9
68	14.2
70	12.9
72	11.4
74	11.1
75	11.3
76	11.5
78	13.2
80	13.7
81	14.2
85	13.5

DATA SET 6* (T = 293 K)

C	ρ
75	8.86

DATA SET 7 (T = 303 K)

C	ρ
0	19.8
4.6	27.6
9.2	35.6
13.8	37.7
18.5	45.0
21.2	49.8
23.6	54.9
25.8	69.0
27.7	93.5
29.1	98.0
30.5	92.6
32.8	99.0
36.9	80.0
55.4	39.1
73.8	27.4
83.0	21.8
92.3	20.0

DATA SET 8 (T = 303 K)

C	ρ
0	19.8
4.6	27.5
9.2	36.2
13.8	39.1
18.5	41.3
81.2	45.5
23.6	42.9
25.8	38.8
27.7	41.7
29.1	42.6
30.5	51.3
32.8	99.0

DATA SET 9 (T = 4.2 K)

C	ρ
33.9	46.0
36.2	34.5
37.4	27.5
38.9	22.3
41.0	17.4
42.9	14.3
45.1	12.1
47.0	10.4
49.9	8.8
52.5	7.7
55.7	6.8
59.0	6.1
69.9	4.4
95.2	1.8
93.1	0.6

DATA SET 10 (T = 297 K)

C	ρ
0.26	13.1
0.53	15.4
1.02	16.9
1.84	16.4
6.73	26.9
7.80	26.7
9.75	28.6
10.80	29.4
11.55	30.3
12.55	34.8
18.45	36.2
21.26	38.7
24.27	63.2
25.44	65.5
27.41	82.0
33.96	81.1
45.84	44.7
74.11	22.1

DATA SET 11 (T = 293 K)

C	ρ
1.2	12.6
2.4	15.3
3.0	14.7
5.0	20.4

DATA SET 12 (T = 303 K)

C	ρ
0	10.5
9.6	30.1
24.1	32.4
29.0	51.4
38.8	65.6
48.8	41.9
58.8	30.7
63.9	25.7
74.1	18.9
77.6	18.2
80.2	17.1
100	7.0

DATA SET 13 (T = 4.2 K)

C	ρ
96.15	1.328
98.03	0.683
98.30	0.652*
98.80	0.473
99.11	0.349
99.50	0.202

DATA SET 14 (T = 273 K)

C	ρ
3.8	20.1
6.7	23.9
12.4	32.0
13.4	33.2
17.3	35.2
20.2	37.8
21.26	38.3
25.44	32.8
33.96	90.0
38.8	69.7
45.84	44.0
89.5	14.3

DATA SET 15 (T = 293 K)

C	ρ
3.8	20.9
6.7	25.2
12.4	33.0
13.4	33.9
17.3	35.9
20.2	38.8
21.26	40.0
25.44	35.9
33.96	92.0
38.8	74.1
45.84	47.5
89.5	15.5

DATA SET 16 (T = 373 K)

C	ρ
3.8	24.1
6.7	31.1
12.4	38.2
13.4	37.8
17.3	37.8
20.2	44.1
21.26	45.0
25.44	37.8
33.96	100.0
38.8	85.8
45.84	60.0
89.5	20.0

* Not shown in figure.

TABLE 63. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM (Composition Dependence) (continued)

DATA SET 17 (T = 473 K)

C	ρ
3.8	31.1
6.7	38.0
12.4	44.3
13.4	45.2
17.3	45.3
20.2	52.2
21.26	53.5
25.44	45.0
33.96	108.2
38.8	102.0
45.84	75.5
89.5	26.4

DATA SET 18 (T = 573 K)

C	ρ
3.8	38.9
6.7	46.1
12.4	53.0
13.4	53.3
17.3	52.8
20.2	61.5
21.26	62.4
25.44	52.6
33.96	114.8
38.8	114.3
45.84	92.0
89.5	35.0

DATA SET 19 (T = 673 K)

C	ρ
3.8	48.0
6.7	54.1
12.4	62.0
13.4	62.4
17.3	63.1
20.2	71.2
21.26	72.4
25.44	62.5
33.96	119.0
38.8	121.3
45.84	103.0
89.5	45.0

DATA SET 20 (T = 773 K)

C	ρ
3.8	58.8
6.7	67.0
12.4	72.4
13.4	72.7
17.3	70.8
20.2	82.0
21.26	82.0
25.44	71.9
33.96	123.0
38.8	124.6
45.84	108.8
89.5	55.2

DATA SET 21 (T = 873 K)

C	ρ
3.8	70.6
6.7	79.0
12.4	86.9
13.4	85.9
17.3	90.0
20.2	109.0
21.26	108.0
25.44	102.8
33.96	126.0
38.8	127.2
45.84	112.0
89.5	62.8

DATA SET 22 (T = 973 K)

C	ρ
3.8	85.0
6.7	94.6
12.4	110.0
13.4	108.2
17.3	106.4
20.2	113.8
21.26	111.6
25.44	110.9
33.96	129.0
38.8	129.0
45.84	114.0
89.5	66.3

DATA SET 23 (T = 1573 K)

C	ρ
0	120.1
5	126.9
15	131.2
30	128.5
45	125.5
65	121.9
85	95.8
100	58.5

DATA SET 24 (T = 1873 K)

C	ρ
0	136.7
5	135.4
15	139.1
30	141.1
45	139.1
65	137.7
85	105.8
100	88.6

DATA SET 25 (T = 293 K)

C	ρ
29.5	82.9
30.1	83.9
31.1	83.1
32.0	79.7
33.7	73.1
36.2	66.3
38.7	58.2

DATA SET 26 (T = 4.2 K)

C	ρ
0	2.58
33.6	50
36.8	31.2
43.7	18.8
58.7	10.4
75.1	6.15
100	1.18

DATA SET 27 (T = 4.2 K)

C	ρ
34.54	38.3
35.74	30.6
36.47	24.8
43.63	11.3
49.59	9.1

DATA SET 28 (T = 873 K)

C	ρ
2.5	72.5
7.2	85.6
12.6	101.5
16.5	108.9
19.3	112.9
24.3	118.0
29.6	120.7
34.4	122.4
39.4	122.3
45.8	122.2
51.6	119.3
59.4	112.3
64.4	107.1
69.1	101.4
75.2	92.7
79.4	86.4
84.4	77.1
87.4	71.4
93.5	59.9
99.9	49.5

DATA SET 29 (T = 300 K)

C	ρ
29.2	83.0
30.9	85.3
32.0	86.4
33.1	87.0
34.0	85.8
37.8	72.1
39.8	65.2
43.3	52.0
45.3	44.5
46.9	38.8
48.6	33.6

DATA SET 29 (cont.) (T = 300 K)

C	ρ
50.2	29.6
53.1	26.1
56.9	21.5
60.0	19.2
64.4	16.8
68.3	15.6
73.9	14.4
79.7	13.8
85.8	13.7
91.4	13.6
95.0	12.4
98.4	10.7
100.0	8.9

DATA SET 30 (T = 293 K)

C	ρ
0	10.5
2.14	16.33
3.16	18.74
3.86	21.18
9.65	30.66
19.26	35.4
25.00	32.64
27.82	68.20
28.05	75.9
32.31	83.2
39.55	55.9
43.50	43.4
49.25	35.21
51.29	32.92
55.39	25.63
62.54	19.9
66.30	17.8
74.68	19.5
79.10	14.8
84.77	13.7
88.65	13.0
96.74	9.82
100	7.4

DATA SET 31* (T = 293 K)

C	ρ
0.0	11.1
20.05	36.1
33.4	84.9
50.16	37.15
75.6	22.4
80	16.57
100	7.88

DATA SET 32 (T = 1473 K)

C	ρ
0.0	119.0
4.0	118.4
7.4	120.1
10.7	121.3
18.1	120.1
21.1	119.6
36.2	119.6
45.2	118.4
54.2	117.9
62.2	117.3
74.6	104.3
96.1	54.3
100	52.6

DATA SET 33 (T = 1873 K)

C	ρ
0	134.3
3.4	131.5
6.8	132.1
10.2	136.0
16.9	134.9
26.6	137.7
35.6	136.6
45.2	136.6
55.4	136.0
62.1	134.9
68.9	132.1
74.6	127.0
87.0	111.6
97.2	90.1
100	84.4

* Not shown in figure.

TABLE 63. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF IRON-NICKEL ALLOY SYSTEM (Composition Dependence) (continued)

C	ρ
DATA SET 34 (T = 4.2 K)	
35.8	41.7
42.4	24.6
48.1	17.2
50.7	15.1
75.0	4.6
DATA SET 35 (T = 4.2 K)	
95.4	1.80
98.2	0.713
99.2	0.307
DATA SET 36* (T = 4.2 K)	
1	1.9
2	2.6
97.05	1.032
98.94	0.370
99.80	0.070
DATA SET 37* (T = 24 K)	
97.05	1.056
98.94	0.424
99.80	0.128

* Not shown in figure.

3.10. Silver-Palladium Alloy System

The preponderance of available evidence [264,289,321] suggests that the silver-palladium alloy system forms a continuous series of solid solutions without the formation of long-range ordered structure. However, the results of electrical resistivity measurements by Savitskii and Pravoverov [368,369] have suggested to the contrary, which will be discussed later in detail as it bears directly on the evaluation of electrical resistivity data for these alloys.

Investigations of the effect of plastic deformation on the electrical resistivity of silver-palladium alloys have been undertaken by Aarts and Houston-MacMillan [370], Rao [371], Nicholson and co-workers [372-374], and others and have shown an anomalous decrease of resistivity with increasing deformation. These investigations, together with isochromal and isothermal annealing studies of recovery processes and Hall constant measurements, have been interpreted (see, for example, ref. [373]) as showing the existence of short-range ordering the silver-palladium alloy system. No x-ray evidence for the existence of short-range order in these alloys exists, probably because the scattering factors for silver and palladium atoms are nearly the same. In an x-ray investigation of a range of alloy compositions, Rao and Rao [375] found that the variation of lattice parameter with temperature deviates from a straight line, but concluded that their results could not be explained by the formation of short-range order.

There are 123 sets of data available for the electrical resistivity of this alloy system. These experimental data sets are listed in tables 65, 67, and 69 which provide information on specimen characterization and measurement conditions, tabulated in tables 66, 68, and 70, and shown partially in figures 53, 54, and 56.

Resistivity values reported for Ag-Pd alloys show striking discrepancies. Residual resistivities given for alloys with 50% silver differ by as much as 13%, and the room-temperature resistivities by 35%. Large differences occur even within the work of single authors; for instance, Kemp et al. [376] (Ag + Pd data sets 41 and 42) report for two samples with 60% silver (wire and rod, respectively) residual resistivities that differ by over 5%, and changes in resistivity to 300 K that differ by 25%. The discrepancies are such as to

indicate that the preparation of Ag-Pd alloys of known composition, good homogeneity, and predictable resistivity offers serious (and perhaps unexpected) difficulties.

Praroverov and Savitskii [368,369] (Ag + Pd data sets 58-61, Pd + Ag data sets 32-35, and Ag-Pd data set 23) have reported measurements on Ag-Pd alloys subjected to very prolonged annealing (124 hours at 1273 K, followed by 200 hours at 1073 K), with results very different from those of other workers. For alloys with over 70% silver they report essentially the same room-temperature resistivities as do other workers, but for alloys richer in palladium their values are much lower. A plot of their resistivity values against the atomic fraction of silver clearly indicates a downward cusp at 40% silver, where they obtain $\rho_{300} = 28 \times 10^{-8}\,\Omega\,m$, about 2/3 as large as the values obtained by others; in addition, their value for 50% silver is quite low, suggesting the presence of a kink, if not a cusp, at this composition. Plots of microhardness against composition show well-defined downward cusps at both compositions. Pravoverov and Savitskii attribute these features to the existence of ordered structures corresponding to the compounds Pd_3Ag_2 and PdAg. Samples quenched from 1123 K, 1273 K, and 1373 K show progressive lessening of these features, and they are entirely absent from a plot of the resistivities of samples quenched from 1473 K, as they are from a plot of microhardness against composition. The results of Pravoverov and Savitskii provide a clear indication that the order in Pd + Ag alloys can increase slowly during prolonged anneals, becoming quite high for certain composition, and that the heat treatment of these alloys can markedly affect their electrical resistivity. The thermal histories of samples used by other workers in this field are often inadequately described, but they seem to be diverse enough to account for a good deal of the scatter in the reported results.

The difference of the results of Pravoverov and Savitskii from those of all other workers with Pd + Ag alloys is so great as to suggest that they are dealing with an essentially different, more ordered, material. Unfortunately, there is also some question as to the accuracy of their measurements. In the case of the alloy with 15% palladium, their room-temperature resistivity fits in well with the results of others, but their reported increase in resistivity with temperature is less than half that reported by a number of other workers for Ag-rich alloys. Their experimental arrangement for measurements at high

temperatures, though inadequately described, appears to be unconventional, and may be responsible for the fact that their high-temperature resistivities are consistently lower than those of other workers. It is not clear whether this can have any relation to the low values that they find for Pd-rich alloys at room temperature. At any rate, their data are not used in our analysis.

The Ag-Pd system is of great theoretical interest. Mott and Jones [6, p. 297ff.] pointed out that the d-states of the transition metal Pd have little effect on electrical conduction in the silver-rich alloys, but that electron scattering into these states comes to be the dominating factor, and produces a striking change in the behavior of the alloys as the concentration of Pd increases. A useful survey of the problem is given by Mott [377, p. 372ff.]. A number of calculations have been based on the model of Mott and Jones, but their success has been mainly qualitative rather than quantitative. It is now evident why the behavior of the system is so complex, but the theory has suggested no useful analytic form for representation of the residual resistivities of the system, or of the even more striking peculiarities of the temperature-dependent part of the resistivities, $\rho-\rho_0$, which are illustrated in figure 55.

The difficulty of making a rational choice between divergent data without the assistance of a suitable theory has made it difficult (despite the relative abundance of data) to arrive at recommended values for the electrical resistivity that have small limits of error. The division of the total resistivity, for purposes of analysis, into residual and temperature-dependent parts is less useful for the attainment of accuracy in the total than it is when the parts exhibit a simpler behavior. This approach has been used, however, to obtain recommended values that reflect, as well as may be, those features in the behavior of the temperature-dependent part that are reliably indicated by the data. It is believed that the trends in the temperature-dependent part of the resistivity are more accurately represented by the recommended values than might be suggested by the error limits (absolute, not fractional) assigned to the total resistivities.

The greater part of the available data relates to residual and room-temperature resistivities. The difference between these quantities can best be determined from measurements of the two quantities made on a single sample, since this minimizes the effect of many errors, including those of sample

characterization. In our analysis the data of Kemp et al. [376] (Ag + Pd data sets 29-44, Pd + Ag data sets 13-18, and Ag-Pd data sets 10-13), Ricker and Pflüger [378] (Ag + Pd data sets 11-15 and Pd + Ag data sets 3-6), and Coles and Taylor [45] (Pd + Ag data set 1 and Ag-Pd data set 3) were used in determining values for $\rho(c,300\ K) - \rho(c,0\ K)$ over the entire range of c. (The wire data of Kemp et al. were given preference over their rod data, since only the wire data extended to intermediate temperatures.) The individual contours for $\rho(c,0\ K)$ and $\rho(c,300\ K)$ were then determined from the entire mass of data at liquid-helium and room temperatures, subject to the constraint of their established separation. This correlation of low- and room-temperature data in determining $\rho(c,0\ K)$ resolved some problems of choice, and appeared to give a significant improvement in the accuracy with which $\rho(c,0\ K)$ could be determined.

Below room temperature, the data of Kemp et al. [376] gives a reasonable coverage of the silver-rich alloys, but leaves serious gaps between 5% and 30% silver and between 30% and 50% silver. The second of these gaps is filled by the data of Ahmad and Greig [175] (Pd + Ag data set 22) and of Coles and Taylor [45]. In the first gap one must use the data of Ricker and Pflüger [378], which is scantier and less well presented. Ricker and Pflüger made no measurements below liquid-air temperature, and they apparently extrapolated their curves to 0 K in rather rough fashion. Their data for each of their samples, as read from their curves, have been adjusted to fit our recommended values for $\rho(c,300\ K)$ by addition of an appropriate constant, with results that are useful down to about 100 K. At temperatures below 40 K the work of Murani [379] (Ag + Pd data sets 52-56 and Pd + Ag data sets 19-21), Edwards et al. [380] (Ag + Pd data sets 23-25 and Pd + Ag data sets 7-10), and Chen et al. [381] (Ag + Pd data sets 7-10) has provided values of ρ_i (not always concordant) for a wide range of compositions. (The values given by Murani for alloys with 62% and 70% silver are quite out of line with other results, and have been ignored.) The work of Greig and Rowlands [382,383] (Pd + Ag data sets 23-26) provides values of ρ_i for dilute alloys with up to 2% Ag in Pd, and the work of Schroeder et al. [180] (Ag + Pd data sets 1-4) gives values of ρ_i for up to 10% Pd in Ag.

In general, the analysis of these data began with the construction of smoothed temperature plots of ρ_i for the individual samples. In the case of

dilute alloys, interpolation and smoothing was facilitated by working with the ratio of the reported ρ_i to that of the pure metal, or its differences from that of the pure metal - that is, the deviation from Matthiessen's rule (DMR). Values read from these curves were then used in constructing a family of isotherms of ρ_i over the whole range of composition, from which were read values for the compositions to appear in the tables. Finally, the values thus obtained were used in constructing smoothed plots against T of ρ_i (or of a ratio or difference), from which values were read for the temperatures to appear in the table.

It may be mentioned that Kemp et al. considered the deviations from Matthiessen's rule to be insignificant for up to 30% Pd in Ag. Schroeder et al., however, found small but measurable values for the DMR appearing rather abruptly in their sample with 10% palladium; they attribute this to disengagement of the Fermi surface from the zone boundary. Since the data of Coles and Taylor support the conclusion of Kemp et al. that the DMR remains very small for up to 30% palladium, we have used the data of Schroeder et al. for alloys with up to 10% palladium (which indicates that the DMR is negligible for alloys with less than 5% palladium) and have taken the DMR to be constant thereafter for alloys with up to 30% palladium, except at temperatures below 100 K, where the very-low-temperature isotherms indicate some variation in this practically negligible quantity.

The extension of the analysis to temperatures above 300 K had to be based primarily on the data of Ricker and Pflüger, normalized to the recommended values for 300 K, as noted above. For concentrated alloys there exist also the data of Coles and Taylor [45] (Pd + Ag data set 1) for an alloy with 39% silver, and the data of Ahmad and Greig [1[illegible]5] (Pd + Ag data set 22) for an alloy with 40% silver. Their results are in reasonable agreement with those of Ricker and Pflüger, and the results of Ahmad and Greig were actually given preference for the 40% Ag alloys, since they provide a value of ρ_0 measured on the same sample. Measurements of Arajs et al. [384] (Ag + Pd data set 57, Pd + Ag data sets 27-31, and Ag-Pd data set 25), still unpublished when this analysis was made, are in reasonable agreement with other results at room temperature, but indicate a much greater increase in resistivity at high temperatures.

No data exists for dilute solutions of Ag in Pd above room temperature. The interpolation between results for pure palladium and an alloy with 10% Ag was made by assuming that there would be a continuation of the tendency, indicated by the low-T data, for the range of concentration in which the DMR is positive to decrease to insignificance as T rises.

The data for dilute (<30%) solutions of Pd in Ag offers some problems. The data of Schroeder et al. [180] indicate that the DMR of a 10 percent alloy is positive and essentially constant from 100 K to 250 K. On the other hand, the data of Ricker and Pflüger for T > 300 K yield ρ_i-plots for alloys with 10, 20, and 30% palladium that sag markedly below the pure-silver plot as temperature rises, yielding negative DMR but at the same time indicating that the DMR is increasing algebraically over this range. If this were true, it would mean that above 300 K the DMR becomes negative and fairly large (over 0.5 x 10^{-8} Ω m) with increasing palladium concentration, but that this tendency is sharply reversed before 10% palladium is reached, with the DMR increasing thereafter. The data of Otter [226] (Ag + Pd data sets 19-22) for alloys with 1, 2, 3, and 4% palladium, though not obtainable from his figures with high accuracy, is inconsistent with this idea. We have accepted as working hypothesis the idea that through some systematic error the resistivity values of Ricker and Pflüger tend to be too low at high T, with the error greater the lower the total resistivity of the specimen. We have therefore followed the suggestion of the low-T data in assuming that the DMR of these alloys is positive and constant for all T > 150 K. A corresponding small modification, well within the limits of error, has been made in the high-T data of Ricker and Pflüger for alloys with 40% and 50% palladium.

From this point, the analysis followed the lines indicated above for the low-T data. The 300 K isotherm of ρ_i, which equals (ρ-ρ_0), derived from low-temperature data and illustrated in figure 55, shows a minimum for about 40% silver and a maximum for about 52% silver, as was noted earlier by Coles and Taylor. As the temperature rises, these features of the isotherms are increasingly marked. Addition of ρ_0 to ρ_i yields isotherms of ρ that are increasingly flattened for silver concentrations around 40%, and the 1100 K isotherm actually has a slight dimple in this region. Changes in the analysis of the existing data can decrease the depth of this dimple, but the existence of the deep minima in the isotherms of ρ_i, and of the flattening in the isotherms of ρ, is indicated

by all data. This unexpected form of the isotherms of ρ would certainly make trouble in an analysis based on direct consideration of ρ, and might well lead to some smoothing out of a real feature of the isotherms.

The resulting recommended electrical resistivity values for Ag, Pd, and for 25 Ag-Pd binary alloys are presented in table 64 and shown in figures 51, 52, and 56. The recommended values for Ag and for Pd are for well-annealed high-purity specimens, but those values for temperatures below about 100 K are applicable only to Ag and Pd having residual electrical resistivities as given at 1 K in table 64. The recommended values for Ag-Pd alloys are intended to apply to samples that are well homogenized and are annealed to remove the effects of cold work, but that have not been subjected to very prolonged annealing such as that which seems to have produced the relatively ordered alloys measured by Pravoverov and Savitskii. This is hardly an ideal characterization of a material, but no more precise one can be given for the materials from which our recommended values have been derived. The recommended values cover the temperature range from 1 K to 1100 K, and are not corrected for the thermal expansion of the material. The uncertainties assigned to the recommended values, as indicated in a footnote to table 64, are intended to represent the possible effects of measurement errors and of other difficulties in our analysis, and also include some allowance for differences in the structure of different carefully prepared samples. This latter allowance is based on the scatter in existing data but can not be precisely defined; certainty it does not define a range that includes all existing results, or all future ones. A better characterization of these alloys, and some precise reference values, are much to be desired.

TABLE 64. RECOMMENDED ELECTRICAL RESISTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM†

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Ag: 100.00% (100.00 At.%) Pd: 0.00% (0.00 At.%)		Ag: 99.50% (99.49 At.%) Pd: 0.50% (0.51 At.%)		Ag: 99.00% (98.99 At.%) Pd: 1.00% (1.01 At.%)		Ag: 97.00% (96.96 At.%) Pd: 3.00% (3.04 At.%)		Ag: 95.00% (94.93 At.%) Pd: 5.00% (5.07 At.%)		Ag: 90.00% (89.88 At.%) Pd: 10.00% (10.12 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	0.00100	1	0.210	1	0.421	1	1.262*	1	2.102*	1	4.20
4	0.00100	4	0.210	4	0.421	4	1.262	4	2.102	4	4.20
7	0.00103	7	0.210	7	0.421	7	1.262	7	2.102	7	4.20
10	0.00115	10	0.210	10	0.421	10	1.262	10	2.103	10	4.20
15	0.00190	15	0.211	15	0.422	15	1.263	15	2.105	15	4.21
20	0.00423	20	0.213	20	0.424	20	1.265	20	2.110	20	4.22
25	0.00959	25	0.218	25	0.429	25	1.270	25	2.118	25	4.23
30	0.0195	30	0.229	30	0.440	30	1.281	30	2.129	30	4.24
40	0.0541	40	0.263	40	0.474	40	1.315	40	2.164	40	4.29
50	0.104	50	0.313	50	0.524	50	1.365	50	2.213	50	4.36
60	0.163	60	0.372	60	0.583	60	1.424	60	2.269	60	4.43
70	0.226	70	0.435	70	0.646	70	1.487	70	2.329	70	4.50
80	0.290	80	0.499	80	0.710	80	1.551	80	2.396	80	4.57
90	0.355	90	0.564	90	0.775	90	1.616	90	2.463	90	4.65
100	0.419	100	0.628	100	0.839	100	1.680	100	2.528	100	4.72
150	0.723	150	0.938	150	1.149	150	1.990	150	2.838	150	5.07
200	1.031	200	1.240	200	1.451	200	2.292	200	3.140	200	5.38
250	1.330	250	1.539	250	1.750	250	2.59	250	3.44	250	5.68
273	1.468	273	1.676	273	1.891	273	2.73	273	3.58	273	5.82
293	1.587	293	1.796	293	2.007	293	2.85	293	3.70	293	5.94
300	1.629	300	1.838	300	2.049	300	2.89	300	3.74	300	5.98
350	1.930	350	2.14	350	2.35	350	3.19	350	4.04	350	6.23
400	2.236	400	2.45*	400	2.66	400	3.50	400	4.34	400	6.39
500	2.863	500	3.07*	500	3.28	500	4.12	500	4.97	500	7.21
600	3.509	600	3.72*	600	3.93	600	4.77	600	5.62	600	7.86
700	4.174	700	4.38*	700	4.59	700	5.43	700	6.28	700	8.52
800	4.860	800	5.07*	800	5.28*	800	6.12*	800	6.96*	800	9.21
900	5.565	900	5.77*	900	5.98*	900	6.83*	900	7.64*	900	9.91
1000	6.297	1000	6.51*	1000	6.72*	1000	7.56*	1000	8.38*	1000	10.64
1100	7.085	1100	7.29*	1100	7.50*	1100	8.35*	1100	9.20*	1100	11.43
1200	7.922										
1235.08	8.233(s)										
1236	17.31(ℓ)										
1400	18.69										
1600	20.38										

† Uncertainties in the electrical resistivity values are as follows:

100.00 Ag – 0.00 Pd: ±1% up to 10 K, ±5% above 10 K to 30 K, ±2% above 30 K to 70 K, ±1% above 70 K to 400 K, ±2% above 400 K to 1235.08 K, and ±4% above 1235.08 K.
99.50 Ag – 0.50 Pd: ±5% below 70 K, ±3% from 70 to 300 K, and ±2% above 300 K.
99.00 Ag – 1.00 Pd: ±4% below 70 K, ±3% from 70 to 300 K, and ±2% above 300 K.
97.00 Ag – 3.00 Pd: ±4% up to 100 K and ±3% above 100 K.
95.00 Ag – 5.00 Pd: ±4% up to 100 K and ±3% above 100 K.
90.00 Ag – 10.00 Pd: ±3% up to 500 K and ±4% above 500 K.

* In temperature range where no experimental data are available.

TABLE 64. RECOMMENDED ELECTRICAL RESISTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Ag: 85.00% (84.82 At.%) Pd: 15.00% (15.18 At.%)		Ag: 80.00% (79.78 At.%) Pd: 20.00% (20.22 At.%)		Ag: 75.00% (74.74 At.%) Pd: 25.00% (25.26 At.%)		Ag: 70.00% (69.71 At.%) Pd: 30.00% (30.29 At.%)		Ag: 65.00% (64.69 At.%) Pd: 35.00% (35.31 At.%)		Ag: 60.00% (59.67 At.%) Pd: 40.00% (40.33 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	6.30*	1	8.39	1	10.52	1	12.91	1	15.7	1	18.8
4	6.30*	4	8.39	4	10.52	4	12.91	4	15.7	4	18.8
7	6.30*	7	8.39	7	10.52	7	12.91	7	15.7	7	18.8
10	6.30*	10	8.39	10	10.52	10	12.91	10	15.7	10	18.8
15	6.31*	15	8.40	15	10.52	15	12.91	15	15.7	15	18.8
20	6.31*	20	8.40	20	10.53	20	12.91	20	15.7	20	18.8
25	6.32*	25	8.41	25	10.53	25	12.92	25	15.7	25	18.8
30	6.34*	30	8.43	30	10.55	30	12.93	30	15.7	30	18.8
40	6.39*	40	8.48	40	10.59*	40	12.98	40	15.8*	40	18.9
50	6.45*	50	8.54	50	10.65*	50	13.04	50	15.8*	50	18.9
60	6.52*	60	8.61	60	10.72*	60	13.11	60	15.9*	60	19.0
70	6.60*	70	8.68	70	10.80*	70	13.19	70	16.0*	70	19.1
80	6.67*	80	8.76	80	10.88*	80	13.27	80	16.1	80	19.2
90	6.75*	90	8.83	90	10.96*	90	13.35	90	16.1*	90	19.3
100	6.82*	100	8.91	100	11.04*	100	13.43	100	16.2*	100	19.4
150	7.17*	150	9.26	150	11.39*	150	13.78	150	16.6*	150	19.9
200	7.48*	200	9.57	200	11.70*	200	14.09	200	17.0*	200	20.3
250	7.78*	250	9.87	250	12.00*	250	14.39	250	17.3*	250	20.7
273	7.92*	273	10.01	273	12.14*	273	14.53	273	17.4*	273	20.9
293	8.04*	293	10.13	293	12.26*	293	14.65	293	17.6*	293	21.1
300	8.08*	300	10.17	300	12.30*	300	14.69	300	17.6*	300	21.2
350	8.38*	350	10.47	350	12.60*	350	14.99	350	18.0*	350	21.6
400	8.68*	400	10.78	400	12.91*	400	15.30	400	18.3*	400	22.0
500	9.31*	500	11.40	500	13.53*	500	15.92	500	18.9*	500	22.8
600	9.96*	600	12.05	600	14.18*	600	16.57	600	19.6*	600	23.6
700	10.63*	700	12.71	700	14.84*	700	17.23	700	20.3*	700	24.4
800	11.31*	800	13.40	800	15.53*	800	17.92	800	21.0*	800	25.2
900	12.00*	900	14.09	900	16.22*	900	18.61	900	21.7*	900	26.0
1000	12.73*	1000	14.83	1000	16.95*	1000	19.34	1000	22.5*	1000	26.8
1100	13.52*	1100	15.62	1100	17.75*	1100	20.14	1100	23.3*	1100	27.7

† Uncertainties in the electrical resistivity values are as follows:

85.00 Ag - 15.00 Pd: ± 3% up to 300 K and ±4% above 300 K.
80.00 Ag - 20.00 Pd: ± 3% up to 300 K and ±4% above 300 K.
75.00 Ag - 25.00 Pd: ± 3% up to 300 K and ±4% above 300 K.
70.00 Ag - 30.00 Pd: ± 3% up to 300 K and ±4% above 300 K.
65.00 Ag - 35.00 Pd: ± 4%.
60.00 Ag - 40.00 Pd: ± 4%.

* In temperature range where no experimental data are available.

TABLE 64. RECOMMENDED ELECTRICAL RESISTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

Ag: 55.00% (54.66 At.%) Pd: 45.00% (45.34 At.%)		Ag: 50.00% (49.66 At.%) Pd: 50.00% (50.34 At.%)		Ag: 45.00% (44.66 At.%) Pd: 55.00% (55.34 At.%)		Ag: 40.00% (39.67 At.%) Pd: 60.00% (60.33 At.%)		Ag: 35.00% (34.69 At.%) Pd: 65.00% (65.31 At.%)		Ag: 30.00% (29.71 At.%) Pd: 70.00% (70.29 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	22.5	1	28.4	1	35.7	1	39.7	1	39.1	1	35.5*
4	22.5	4	28.4	4	35.7	4	39.7	4	39.1	4	35.5
7	22.5	7	28.4	7	35.7	7	39.7	7	39.1	7	35.5
10	22.5	10	28.4	10	35.7	10	39.7	10	39.1	10	35.5
15	22.5	15	28.4	15	35.7	15	39.7	15	39.1	15	35.5
20	22.5	20	28.4	20	35.7	20	39.7	20	39.1	20	35.5
25	22.5	25	28.4	25	35.7	25	39.7	25	39.1*	25	35.5
30	22.6*	30	28.4	30	35.7	30	39.7	30	39.1*	30	35.5
40	22.6*	40	28.5	40	35.8*	40	39.7	40	39.2*	40	35.7
50	22.7*	50	28.6	50	35.9*	50	39.9	50	39.4*	50	35.8
60	22.8*	60	28.7	60	36.1*	60	40.1	60	39.6*	60	36.1
70	22.9*	70	28.9	70	36.2*	70	40.3	70	39.8*	70	36.3
80	23.0	80	29.0	80	36.4*	80	40.4	80	40.0*	80	36.6
90	23.2*	90	29.1	90	36.5*	90	40.6	90	40.2*	90	36.8
100	23.3*	100	29.3	100	36.7*	100	40.8	100	40.4*	100	37.1
150	23.9*	150	29.9	150	37.3*	150	41.4	150	41.2*	150	38.3
200	24.4*	200	30.5	200	37.8*	200	41.9	200	42.0*	200	39.3
250	25.0*	250	31.0	250	38.1*	250	42.1	250	42.5*	250	40.1
273	25.3*	273	31.2	273	38.2*	273	42.2	273	42.7*	273	40.4
293	25.5	293	31.4	293	38.3	293	42.2	293	42.8	293	40.6
300	25.6	300	31.5	300	38.3	300	42.2	300	42.9	300	40.7
350	26.1*	350	32.0	350	38.4*	350	42.3	350	43.1*	350	41.3
400	26.6*	400	32.4	400	38.5*	400	42.3	400	43.3*	400	41.7
500	27.6*	500	33.2	500	38.7*	500	42.2	500	43.5*	500	42.5
600	28.5*	600	34.0	600	39.0*	600	42.2	600	43.7*	600	43.1
700	29.4*	700	34.8	700	39.4*	700	42.1	700	43.8*	700	43.6
800	30.2*	800	35.5	800	39.7*	800	42.2	800	43.9*	800	44.1
900	31.0*	900	36.3	900	40.2*	900	42.3	900	44.1*	900	44.6
1000	31.7*	1000	36.9	1000	40.6*	1000	42.4	1000	44.4*	1000	45.1
1100	32.4*	1100	37.6	1100	41.1*	1100	42.6	1100	44.8*	1100	45.7

† Uncertainties in the electrical resistivity values are as follows:

55.00 Ag - 45.00 Pd: ±4% up to 300 K and ±5% above 300 K.
50.00 Ag - 50.00 Pd: ±3% up to 300 K and ±4% above 300 K.
45.00 Ag - 55.00 Pd: ±2% up to 300 K and ±4% above 300 K.
40.00 Ag - 60.00 Pd: ±2% up to 300 K and ±4% above 300 K.
35.00 Ag - 65.00 Pd: ±2% up to 300 K and ±3% above 300 K.
30.00 Ag - 70.00 Pd: ±2% up to 250 K and ±3% above 250 K.

* In temperature range where no experimental data are available.

TABLE 64. RECOMMENDED ELECTRICAL RESISTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM† (continued)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

Ag: 25.00% (24.74 At.%) Pd: 75.00% (75.26 At.%)		Ag: 20.00% (19.78 At.%) Pd: 80.00% (80.22 At.%)		Ag: 15.00% (14.83 At.%) Pd: 85.00% (85.17 At.%)		Ag: 10.00% (9.88 At.%) Pd: 90.00% (90.12 At.%)		Ag: 5.00% (4.94 At.%) Pd: 95.00% (95.06 At.%)		Ag: 3.00% (2.96 At.%) Pd: 97.00% (97.04 At.%)	
T	ρ	T	ρ	T	ρ	T	ρ	T	ρ	T	ρ
1	30.47	1	24.72	1	18.56*	1	12.37	1	6.18*	1	3.71
4	30.47	4	24.72	4	18.56	4	12.37	4	6.18	4	3.71
7	30.47	7	24.72	7	18.56*	7	12.37	7	6.18	7	3.71
10	30.47	10	24.72	10	18.56*	10	12.37	10	6.18	10	3.71
15	30.47	15	24.72	15	18.57*	15	12.38	15	6.20	15	3.72
20	30.47	20	24.74	20	18.59*	20	12.40	20	6.22	30	3.75
25	30.51	25	24.77	25	18.63*	25	12.45	25	6.27	25	3.80
30	30.56	30	24.83	30	18.69*	30	12.51	30	6.34	30	3.88
40	30.71	40	24.99	40	18.87*	40	12.71	40	6.56	40	4.11
50	30.90*	50	25.21	50	19.11*	50	12.97	50	6.85	50	4.41
60	31.15*	60	25.49	60	19.41*	60	13.29	60	7.19	60	4.77
70	31.43*	70	25.81	70	19.76*	70	13.67	70	7.59	70	5.17
80	31.75*	80	26.16	80	20.14*	80	14.08	80	8.02	80	5.60
90	32.08*	90	26.53	90	20.55*	90	14.52	90	8.46	90	6.05
100	32.40*	100	26.90	100	20.97*	100	14.95	100	8.91	100	6.50
150	33.88*	150	28.67	150	22.97*	150	17.06	150	11.09	150	8.67
200	35.13*	200	30.20	200	24.75*	200	19.03	200	13.15	200	10.72
250	36.20*	250	31.56	250	26.38*	250	20.88	250	15.11	250	12.69
273	36.67*	273	32.15	273	27.08*	273	21.69	273	15.98	273	13.56
293	37.06	293	32.64	293	27.68	293	22.39	293	16.72	293	14.30
300	37.19	300	32.8	300	27.89*	300	22.63	300	16.98	300	14.56
350	38.1*	350	33.9	350	29.3*	350	24.3	350	18.8*	350	16.38*
400	38.8*	400	34.9	400	30.6*	400	25.9	400	20.5*	400	18.14*
500	40.1*	500	36.8	500	33.1*	500	28.9	500	23.8*	500	21.50*
600	41.2*	600	38.5	600	35.3*	600	31.6	600	26.9*	600	24.64*
700	42.1*	700	39.9	700	37.3*	700	34.2	700	29.8*	700	27.6*
800	43.0*	800	41.2	800	39.1*	800	36.6	800	32.5*	800	30.4*
900	43.9*	900	42.5	900	40.8*	900	38.8	900	35.0*	900	32.9*
1000	44.8*	1000	43.7	1000	42.3*	1000	40.8	1000	37.2*	1000	35.3*
1100	45.6*	1100	44.8	1100	43.7*	1100	42.6	1100	39.2*	1100	37.3*

† Uncertainties in the electrical resistivity values are as follows:

25.00 Ag - 75.00 Pd: ±3% up to 300 K and ±4% above 300 K.
20.00 Ag - 80.00 Pd: ±3% up to 300 K and ±4% above 300 K.
15.00 Ag - 85.00 Pd: ±4%.
10.00 Ag - 90.00 Pd: ±4%.
5.00 Ag - 95.00 Pd: ±4% up to 100 K and ±3% above 100 K.
3.00 Ag - 97.00 Pd: ±4% below 50 K, ±3% from 50 to 200 K, and ±2% above 200 K.

* In temperature range where no experimental data are available.

TABLE 64. RECOMMENDED ELECTRICAL RESISTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM† (continued)

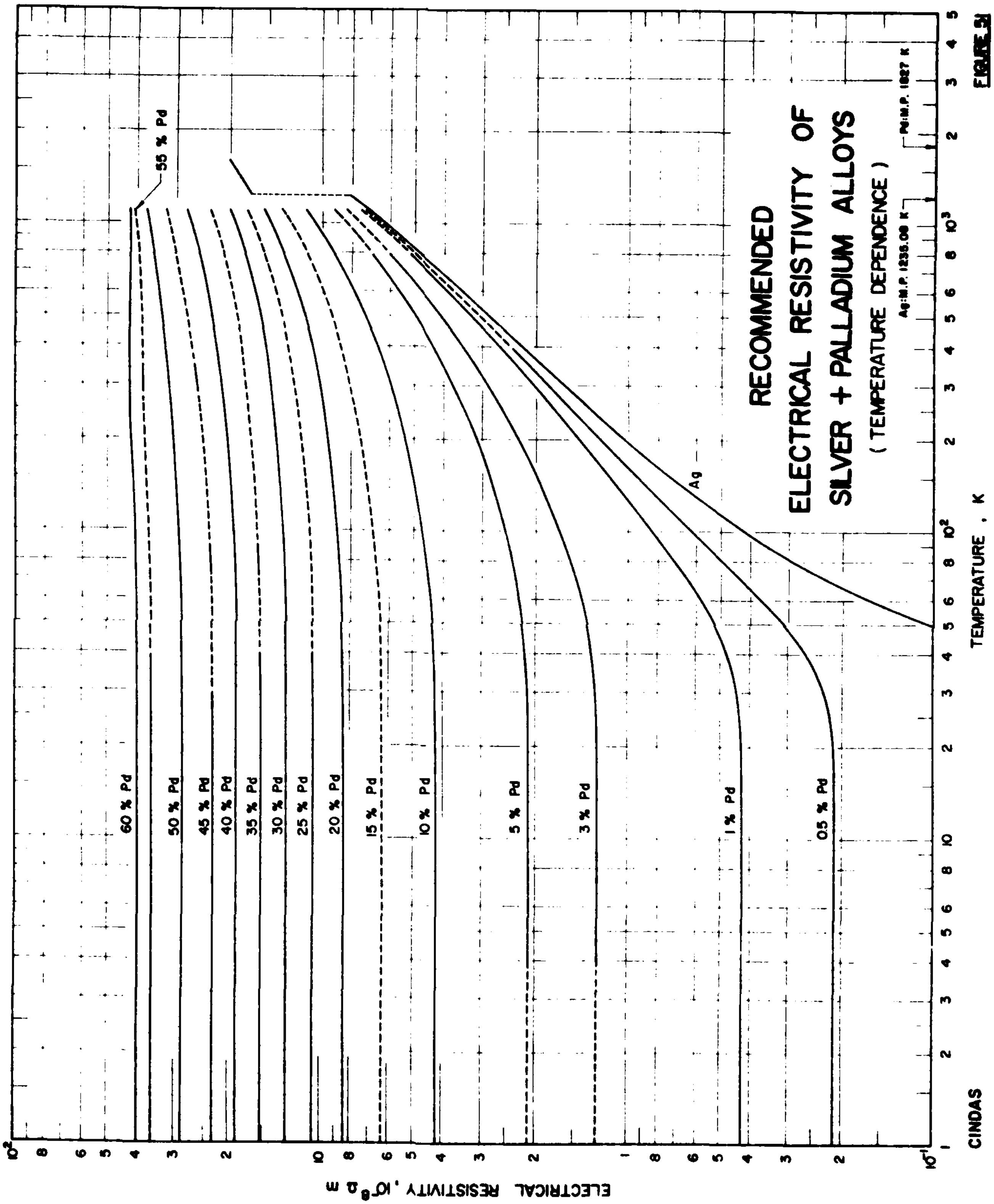
[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega$ m]

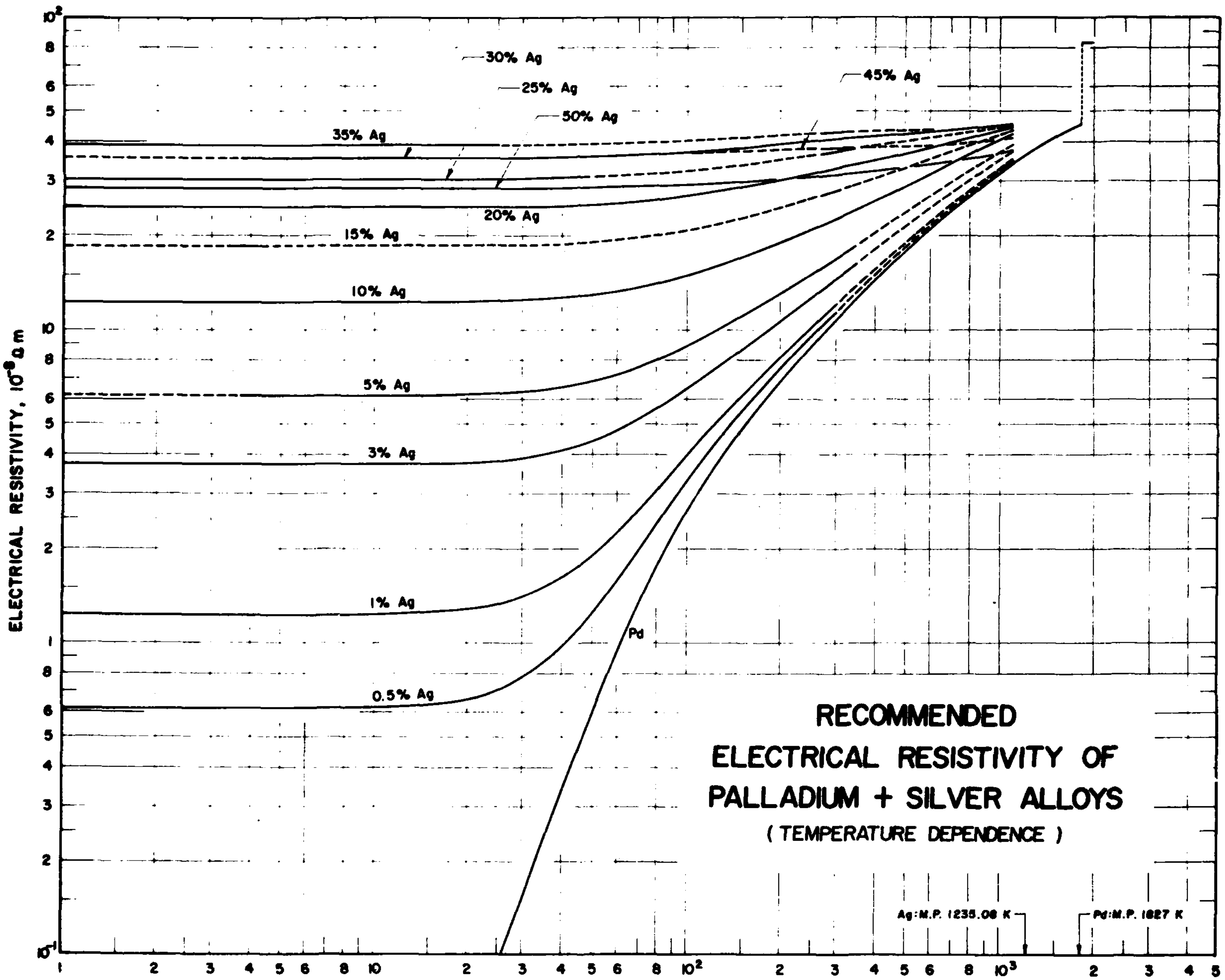
Ag: 1.00% (0.99 At.%) Pd: 99.00% (99.01 At.%)		Ag: 0.50% (0.49 At.%) Pd: 99.50% (99.51 At.%)		Ag: 0.00% (0.00 At.%) Pd: 100.00% (100.00 At.%)	
T	ρ	T	ρ	T	ρ
1	1.236	1	0.617	1	0.0200
4	1.236	4	0.617	4	0.0205
7	1.236	7	0.618	7	0.0217
10	1.240	10	0.622	10	0.0242
15	1.252	15	0.633	15	0.0346
20	1.280	20	0.659	20	0.0564
25	1.33	25	0.705	25	0.0938
30	1.40	30	0.773	30	0.151
40	1.62	40	0.976	40	0.335
50	1.90	50	1.253	50	0.607
60	2.25	60	1.592	60	0.940
70	2.64	70	1.98	70	1.32
80	3.07	80	2.40	80	1.75
90	3.52	90	2.85	90	2.19
100	3.97	100	3.29	100	2.63
150	6.14	150	5.47	150	4.81
200	8.21	200	7.54	200	6.89
250	10.18	250	9.52	250	8.88
273	11.06	273	10.41	273	9.78
293	11.32	293	11.17	293	10.54
300	12.08*	300	11.43*	300	10.80
350	13.92*	350	13.28*	350	12.66
400	15.70*	400	15.07*	400	14.46
500	19.13*	500	18.50*	500	17.89
600	22.32*	600	21.70*	600	21.10
700	25.3*	700	24.7*	700	24.10
800	28.1*	800	27.5*	800	26.[illegible]
900	30.7*	900	30.1*	900	29.50
1000	33.1*	1000	32.5*	1000	31.92
1100	35.2*	1100	34.7*	1200	36.21
				1400	39.80
				1600	42.70
				1827	45.14(s)
				1830	83.0(ℓ)
				2000	83.0

† Uncertainties in the electrical resistivity values are as follows:

1.00 Ag - 99.00 Pd: ±4% up to 50 K and ±2% above 50 K.
0.50 Ag - 99.50 Pd: ±4% up to 50 K and ±2% above 50 K.
0.00 Ag - 100.00 Pd: ±2% up to 40 K, ±1% above 40 K to 350 K, ±2% above 350 K to 1600 K, ±2.5% above 1600 K to 1827 K, and ±5% above 1827 K.

* In temperature range where no experimental data are available.


RECOMMENDED
ELECTRICAL RESISTIVITY OF
SILVER + PALLADIUM ALLOYS
(TEMPERATURE DEPENDENCE)
Ag: M.P. 1235.08 K
Pd: M.P. 1827 K
FIGURE 51
60 % Pd
55 % Pd
50 % Pd
45 % Pd
40 % Pd
35 % Pd
30 % Pd
25 % Pd
20 % Pd
15 % Pd
10 % Pd
5 % Pd
3 % Pd
1 % Pd
0.5 % Pd
Ag
TEMPERATURE , K
ELECTRICAL RESISTIVITY , 10^{-8} Ω m
CINDAS



CINDAS

FIGURE 52

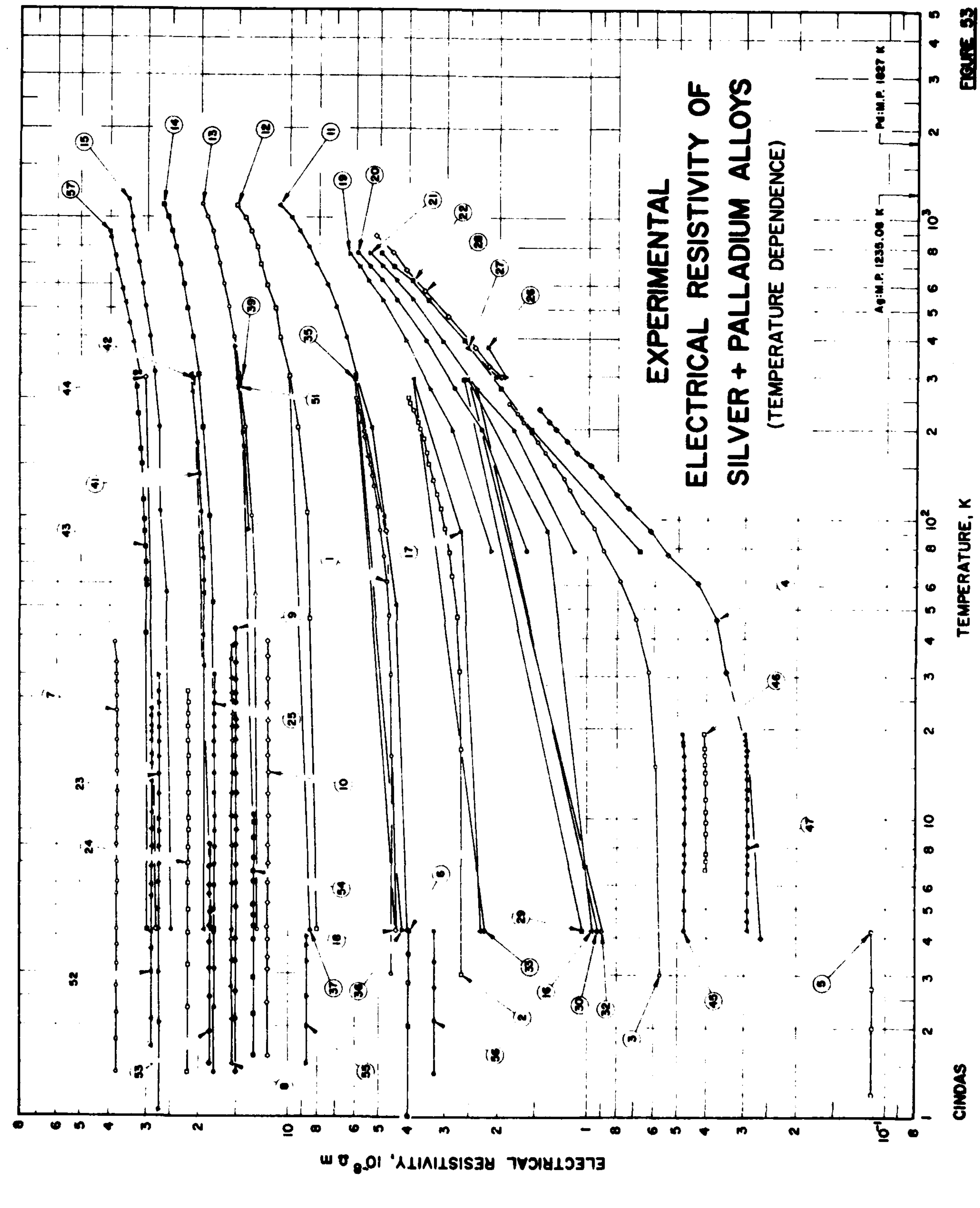

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
SILVER + PALLADIUM ALLOYS
(TEMPERATURE DEPENDENCE)
Ag:M.P. 1235.08 K
Pd:M.P. 1827 K
TEMPERATURE, K
ELECTRICAL RESISTIVITY, 10⁻⁸ Ω m
CINDAS

FIGURE 53

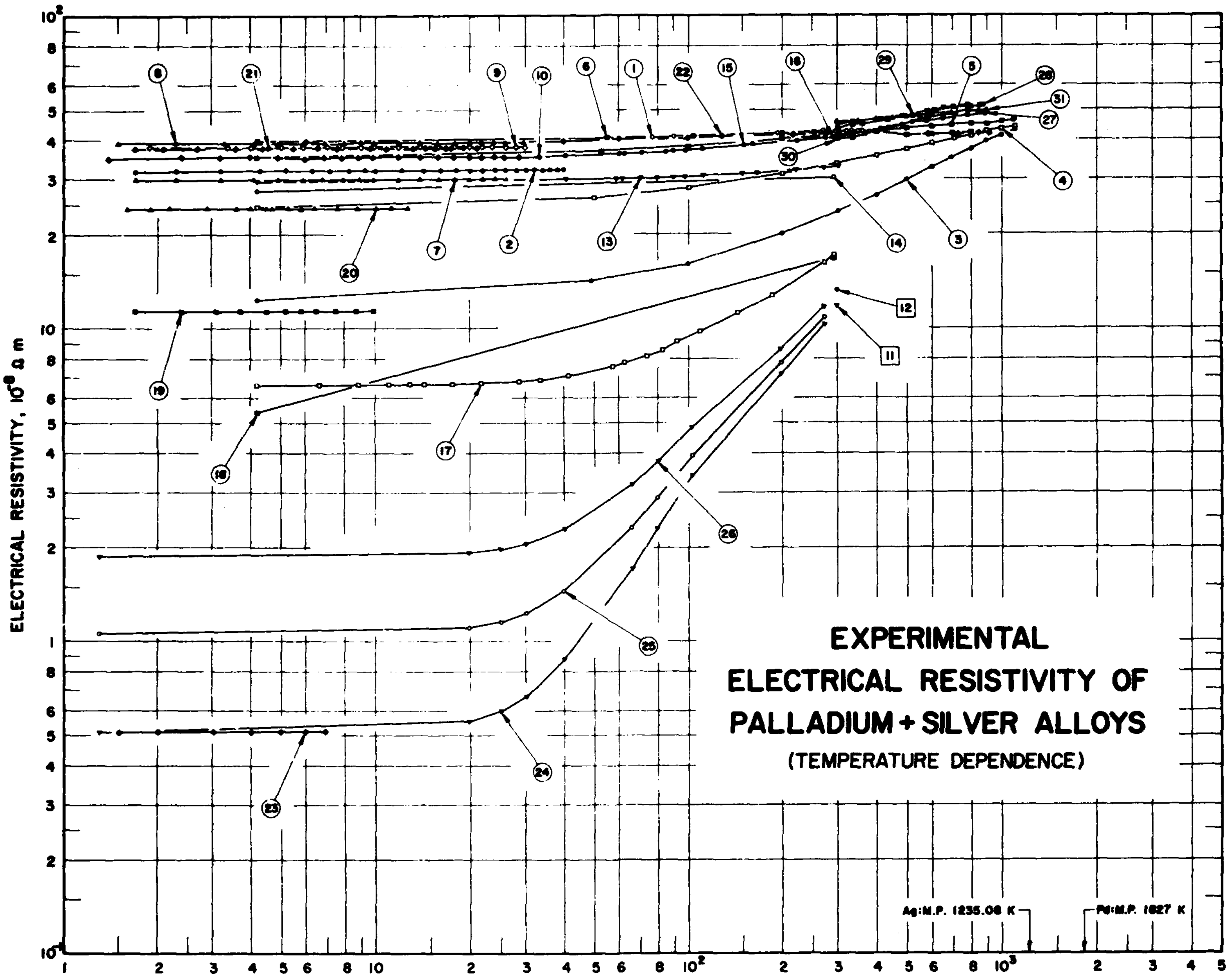

EXPERIMENTAL
ELECTRICAL RESISTIVITY OF
PALLADIUM + SILVER ALLOYS
(TEMPERATURE DEPENDENCE)
ELECTRICAL RESISTIVITY, 10^{-8} Ω m
TEMPERATURE, K
Ag:M.P. 1235.08 K
Pd:M.P. 1827 K
CINDAS

FIGURE 54

TABLE 65. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER + PALLADIUM ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Pd	Composition (continued), Specifications, and Remarks
1	180	Schroeder, P.A., Wolf, R., and Woollam, J.A.	1965	A	3-250			9.88	Calculated composition (10.0 a/o Pd), 15 ±10 ppm Fe impurity; Cominco 59 grade Ag ($R_{273}/R_{4.2}$ = 640) with 3 ±3 ppm Fe and sponge Pd from Johnson-Matthey and Co. Ltd. melted together in alumina crucible by induction heating, chill cast in ingot, drawn down to wire of 0.2 mm diam, and annealed in vacuum at 953 K; cross-sections determined from weight per unit length measurements and the densities of the pure components as given by the supplier and modified to allow for changes of lattice parameter on alloying; data read from figure.
2	180	Schroeder, P.A., et al.	1965	A	3-252			6.22	Calculated composition (6.30 a/o Pd); similar to the above specimen.
3	180	Schroeder, P.A., et al.	1965	A	3-243			1.26	Calculated composition (1.28 a/o Pd); similar to the above specimen.
4	180	Schroeder, P.A., et al.	1965	A	4-232			0.52	Calculated composition (0.53 a/o Pd); similar to the above specimen.
5	283	Bäcklund, N.	1958	A	1.2-4.2			0.207	Calculated composition (0.21 a/o Pd); prepared from spectroscopically pure materials from Johnson Matthey and Co., Ltd. by melting together in evacuated silica tube in high-frequency furnace; ingot slightly rolled, homogenized at 1073 to 1173 K for about 2 h, then drawn to 0.2 mm wire; annealed at about 773 K prior to measurement; negative resistivity-temperature derivative indicated low temperature minimum; data read from figure.
6	283	Bäcklund, N.	1958	A	1.0-4.2			9.40	Calculated composition (9.52 a/o Pd); similar to the above specimen; resistivity-temperature derivative gave no indication of minimum within accuracy of measurements.
7	381	Chen, C.W., Edwards, L.R., and Legvold, S.	1968	A	1.4-38.2		50.3	49.7	Calculated composition (50 a/o Pd), chemical analysis showed 10 to 20 ppm Fe impurity; 99.999 pure Ag and 99.99 pure Pd levitation melted, swaged, drawn to wires of about 1 mm diam, cut to length of 5 cm, annealed in vacuum at 1273 K to recrystallize, and furnace-cooled; sample temperature controlled within ±0.05 K, relative error about ±0.0004 x 10^{-8} Ωm, ±1% uncertainty in resistivity due to slightly non-uniform diam; data read from figure.
8	381	Chen, C.W., et al.	1968	A	1.4-37.7	A	65.3	34.7	Calculated composition (35 a/o Pd); similar to the above specimen.
9	381	Chen, C.W., et al.	1968	A	1.4-42.4	A'	65.3	34.7	The above specimen reheated to 1273 K and quenched in ice water.
10	381	Chen, C.W., et al.	1968	A	1.6-38.6		75.2	24.8	Calculated composition (25 a/o Pd); similar to the sample of Ag + Pd data set 7.
11	378	Ricker, T. and Pflüger, E.	1966	B	4.2-1103			9.9	Calculated composition (10 a/o Pd); 0.35 to 0.5 mm in diam and 50 to 100 cm long; supplied by Firma Degussa; prepared from 99.9 pure palladium and 99.99 pure silver; annealed in argon at 1073 K for 30 min and quenched in water; data read from figure.
12	378	Ricker, T. and Pflüger, E.	1966	B	4.2-1102			19.8	Calculated composition (20 a/o Pd); similar to the above specimen.
13	378	Ricker, T. and Pflüger, E.	1966	B	4.2-1106			29.7	Calculated composition (30 a/o Pd); similar to the above specimen.

TABLE 65. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER + PALLADIUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Pd	Composition (continued), Specifications, and Remarks
14	378	Ricker, T. and Pflüger, E.	1966	B	4.2-1103			39.7	Calculated composition (40 a/o Pd); similar to the above specimen.
15	378	Ricker, T. and Pflüger, E.	1966	B	4.2-1105			49.7	Calculated composition (50 a/o Pd); similar to the above specimen.
16	244	Tainsh, R.J. and White, G.K.	1962		4.2-293			2.05	Calculated composition (2.08 a/o Pd); rod specimen 3 to 5 mm in diam and 6 cm long; annealed at 1213 K; data extracted from table.
17	244	Tainsh, R.J. and White, G.K.	1962		4.2-293			4.99	Calculated composition (5.06 a/o Pd); similar to the above specimen.
18	244	Tainsh, R.J. and White, G.K.	1962		4.2-293			9.78	Calculated composition (9.9 a/o Pd); similar to the above specimen.
19	226	Otter, F.A., Jr.	1956	A	78-767			4.07	Calculated composition (4.12 a/o Pd); 99.99+ silver from Handy and Harman and 99.99+ palladium from Bishop Platinum Co. melted together under vacuum of less than one micron in alundum crucibles with an induction furnace, superheated about 100 K above the melting point to insure solutions in a reasonable time, homogenized in vacuum for 24 h at 1173 K, ingot swaged or drawn to wires of about 0.030 in diam, and annealed about 1 h at 773 to 823 K before measuring in vacuum; data read from figure.
20	226	Otter, F.A., Jr.	1956	A	78-767			2.97	Calculated composition (3.01 a/o Pd); similar to the above specimen.
21	226	Otter, F.A., Jr.	1956	A	78-767			1.97	Calculated composition (2.00 a/o Pd); similar to the above specimen.
22	226	Otter, F.A., Jr.	1956	A	78-767			1.09	Calculated composition (1.10 a/o Pd); similar to the above specimen.
23	380	Edwards, L.R., Chen, C.W., and Legvold, S.	1970		1.1-30		50.34	49.66	Calculated composition (50 a/o Pd), analysis revealed 0.0050 to 0.0250 wt % Fe but authors concluded minimum in resistivity at low temperatures was not due to Fe content; data read from figure.
24	380	Edwards, L.R., et al.	1970		1.4-27		55.34	44.66	Calculated composition (45 a/o Pd); similar to the above specimen.
25	380	Edwards, L.R., et al.	1970		1.4-30		60.33	39.67	Calculated composition (40 a/o Pd); similar to the above specimen.
26	385	Pravoverov, N.L. and Tribunskaya, L.A.	1967	B	298,373	15	99.40	0.6	Composition determined by chemical analysis, microstructural analysis confirmed single phase; 10 g charge of 99.99 pure Ag and electron-beam-refined Pd (99.98 initial purity) melted in double evacuated quartz ampoules in high frequency furnace, homogenized in vacuum at 673 K for 60 h, drawn into wires 0.5 and 1 mm diam, and annealed at 623 K for 0.5 h; data extracted from table.
27	385	Pravoverov, N.L. and Tribunskaya, L.A.	1967	B	298,373	17	99.00	1.0	Similar to the above specimen.
28	385	Pravoverov, N.L. and Tribunskaya, L.A.	1967	B	298-873	16	99.20	0.8	Similar to the above specimen; measured in a vacuum of 6 x 10^{-6} mm Hg.
29	376	Kemp, W.R.G., Klemens, P.G., Sreedhar, A.K., and White, G.K.	1956	B	4.2,293			2.08	Wire specimen supplied by Johnson, Matthey and Co. Ltd.; wound on a mica former; measured in strained state; data extracted from table.

TABLE 65. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER + PALLADIUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Pd	Composition (continued), Specifications, and Remarks
30	376	Kemp, W.R.G., Klemens, P.G., Sreedhar, A.K., and White, G.K.	1956	B	4.2,293				The above specimen annealed at 883 K; data extracted from table; authors also gave temperature-dependent resistivity in figure and stated it was the same for all alloys with 2 to 30% Pd.
31*	376	Kemp, W.R.G., et al.	1956	B	4.2,293			2.08	Rod specimen supplied by Johnson, Matthey and Co. Ltd.; measured in strained state; data extracted from table.
32	376	Kemp, W.R.G., et al.	1956	B	4.2,293				The above specimen measured after annealing at 883 K.
33	376	Kemp, W.R.G., et al.	1956	B	4.2,293			5.06	Wire specimen supplied by Johnson, Matthey and Co. Ltd.; wound on a mica former and annealed at 883 K; data extracted from table; authors also gave temperature-dependent resistivity in figure and stated it was the same for all alloys with 2 to 30% Pd.
34*	376	Kemp, W.R.G., et al.	1956	B	4.2,293			5.06	Rod specimen supplied by Johnson, Matthey and Co. Ltd.; annealed at 883 K; data extracted from table.
35	376	Kemp, W.R.G., et al.	1956	B	4.2,293			9.9	Wire specimen supplied by Johnson, Matthey and Co. Ltd.; wound on a mica former and annealed at 923 K; data extracted from table; authors also gave temperature-dependent resistivity in figure and stated it was the same for all alloys with 2 to 30% Pd.
36	376	Kemp, W.R.G., et al.	1956	B	4.2,293			9.9	Rod specimen supplied by Johnson, Matthey and Co. Ltd.; annealed at 923 K; data extracted from table.
37	376	Kemp, W.R.G., et al.	1956	B	4.2,293			20.08	Wire specimen supplied by Johnson, Matthey and Co. Ltd.; wound on a mica former and annealed at 923 K; data extracted from table; authors also gave temperature-dependent resistivity in figure and stated it was the same for all alloys with 2 to 30% Pd.
38*	376	Kemp, W.R.G., et al.	1956	B	4.2,293			20.08	Rod specimen supplied by Johnson, Matthey and Co. Ltd.; annealed at 1073 K; data extracted from table.
39	376	Kemp, W.R.G., et al.	1956	B	4.2,293			29.62	Wire specimen supplied by Johnson, Matthey and Co. Ltd.; wound on mica former and annealed at 923 K; data extracted from table; authors also gave temperature-dependent resistivity and stated it was the same for all alloys with 2 to 30% Pd.
40*	376	Kemp, W.R.G., et al.	1956	B	4.2,293			29.62	Rod specimen supplied by Johnson, Matthey and Co. Ltd.; annealed at 1073 K; data extracted from table.
41	376	Kemp, W.R.G., et al.	1956	B	4.2-300			40	Wire specimen supplied by Johnson, Matthey and Co. Ltd.; annealed at 1153 K, wound on a mica former, and again annealed at 773 K; values of temperature-dependent resistivity read from figure and added to tabulated residual resistivity to obtain total resistivity.
42	376	Kemp, W.R.G., et al.	1956	B	4.2,293			40	Rod specimen supplied by Johnson, Matthey and Co. Ltd.; annealed at 1153 K; data extracted from table.
43	376	Kemp, W.R.G., et al.	1956	B	4.2-303			50	Wire specimen supplied by Johnson, Matthey and Co. Ltd.; annealed at 1153 K, wound on mica former, and again annealed at 773 K; values of temperature-dependent resistivity read from figure and added to tabulated residual resistivity to obtain total resistivity.

* Not shown in figure.

TABLE 65. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER + PALLADIUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Pd	Composition (continued), Specifications, and Remarks
44	376	Kemp, W.R.G., Klemens, P.G., Sreedhar, A.K., and White, G.K.	1956	B	4.2, 293			50	Rod specimen supplied by Johnson, Matthey and Co. Ltd.; annealed at 773 K; data extracted from table.
45	308	Barber, A.J. and Caplin, A.D.	1975	A	4.2-19.4	Sample 43		1.056	Calculated, nominal composition (1.07 a/o Pd); wire specimen 0.76 mm in diam; high purity Ag and Pd melted together in quartz ampoules, homogenized, and rolled and drawn into wire; annealed at 873 K for 6 to 10 h in a sealed capsule with up to 10 Torr oxygen or in a continuous flow of oxygen at 10^{-1} Torr in order to precipitate Fe; measured in helium environment; residual resistivity 0.472×10^{-8} Ωm; uncertainty in temperature less than ±200 mK below 20 K and ± 100 mK below 10 K, less than 1% uncertainty in geometrical factor; data extracted from figure with error bars.
46	308	Barber, A.J. and Caplin, A.D.	1975	A	6.8-19.3	Sample 40		0.888	Calculated, nominal composition (0.90 a/o Pd); similar to the above specimen; 0.89 mm diam; residual resistivity 0.4000×10^{-8} Ωm.
47	308	Barber, A.J. and Caplin, A.D.	1975	A	4.2-19.4	Sample 42		0.651	Calculated, nominal composition (0.66 a/o Pd); similar to the above specimen; 0.65 mm diam; residual resistivity 0.2900×10^{-8} Ωm.
48*	308	Barber, A.J. and Caplin, A.D.	1975	A	4.3-19.8	Sample 57		0.0898	Calculated, nominal composition (0.091 a/o Pd); similar to the above specimen; 0.36 mm diam; residual resistivity 0.0422×10^{-8} Ωm.
49*	308	Barber, A.J. and Caplin, A.D.	1975	A	4.7-19.8	Sample 58		0.0898	Calculated, nominal composition (0.091 a/o Pd); similar to the above specimen; 0.36 mm diam; residual resistivity 0.0415×10^{-8} Ωm.
50*	308	Barber, A.J. and Caplin, A.D.	1975	A	2.1-19.5	Sample 90		0.00769	Calculated, nominal composition (0.0078 a/o Pd); similar to the above specimen; 0.25 mm diam; residual resistivity 0.00607×10^{-8} Ωm.
51	386	Dewar, J. and Fleming, J.A.	1892	B	91-373		80	20	Wire specimen 0.0762 mm (0.003 in) in diam and of the order of 50-100 cm long wound loosely on mica sheet; supplied by Johnson and Matthey; measurements taken in boiling water, air, melting ice, melting carbonic acid, boiling ethylene, and boiling oxygen; diameter measured to nearest 0.01 in; values reported are average of several measurements; no correction for thermal expansion; units of composition not stated, weight percent assumed.
52	379	Murani, A.P.	1974		1.7-23.0		50.3		Calculated composition (50 a/o Ag); preliminary results with no measurement information; data read from figure.
53	379	Murani, A.P.	1974		1.5-8.1		62.3		Calculated composition (62 a/o Ag); similar to the above specimen.
54	379	Murani, A.P.	1974		1.6-10.2		70.3		Calculated composition (70 a/o Ag); similar to the above specimen.
55	379	Murani, A.P.	1974		1.5-4.0		80.2		Calculated composition (80 a/o Ag); similar to the above specimen.
56	379	Murani, A.P.	1974		1.4-4.2		92.1		Calculated composition (92 a/o Ag); similar to the above specimen.
57	384	Arajs, S., Rao, K.V., Yao, Y.D., and Teoh, W.	1977	A	301-896		50.24		Calculated composition (49.9 a/o Ag); 99.99 pure Pd sponge from Engelhard Industries Inc. and 99.999 pure Ag from American Smelting and Refining Co. arc-melted to form ingot weighing about 10 g; ingot sealed in evacuated silica tube, homogenized at about 1300 K for 60 h, drawn to 1 mm^2 cross-section, cleaned, re-sealed in evacuated silica capsule; annealed at 1200 K for 1 h, and rapidly cooled in air without breaking the capsule; measurement temperatures produced by platinum wound vacuum furnace; data read from figure.

* Not shown in figure.

TABLE 65. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER + PALLADIUM ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Ag	Pd	Composition (continued), Specifications, and Remarks
58*	369	Pravoverov, N. L. and Savitskii, E. M.	1962	A	315-1020	3	85.2		Calculated composition (85 a/o Ag); 10 g charge melted under borax in induction furnace, cast, forged, rolled, and vacuum annealed for 120 h at 1273 K and 250 h at 1073 K in order to bring nearly to equilibrium; annealed as 1 mm diam wire, then drawn to 0.3 mm diam and again annealed for 1 h at 1173 K to remove work-hardening; sample specimen consisted of 250 mm of the wire wound into cylindrical coil of mean diam 3 mm and length 2[illegible] mm; coil welded to junctions of two thermocouples consisting of Pt and Pt-Rh electrodes; Pt electrodes formed part of the current-supplying circuit and Pt-Rh ones part of the current-removing circuit; recorded temperature was mean of values for the two thermocouples, with no significant temperature drop along the length of the coil; direction of the specimen current reversed and [illegible]n resistivity recorded; data reported as $\rho(T)/\rho(298)$, the ratio of the resistivity at the measurement temperature (T) to that at 298 K, without reporting $\rho(298)$; data read from figure.
59*	369	Pravoverov, N. L. and Savitskii, E. M.	1962	A	342-1006	4	60.3		Calculated composition (60 a/o Ag); similar to the above specimen.
60*	369	Pravoverov, N. L. and Savitskii, E. M.	1962	A	342-1149	5	55.3		Calculated composition (55 a/o Ag); similar to the above specimen.
61*	369	Pravoverov, N. L. and Savitskii, E. M.	1962	A	297-1173	6	50.3		Calculated composition (50 a/o Ag); similar to the above specimen; according to the authors, ordering takes place in this alloy upon prolonged annealing at 1073 to 1273 K.

* Not shown in figure.

TABLE 66. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF SILVER + PALLADIUM ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, 10^{-8} Ω m]

DATA SET 1

T	ρ
3	4.52
16	4.53
30	4.56
47	4.65
61	4.72
74	4.83
91	4.97
107	5.09
127	5.22
137	5.28
150	5.38
162	5.46
186	5.61
194	5.66
209	5.76
226	5.84
241	5.95
250	6.00

DATA SET 2

T	ρ
3	2.64
17	2.65
31	2.67
47	2.74
64	2.87
77	2.93
92	3.02
107	3.12
121	3.23
134	3.30
153	3.41
166	3.48
185	3.59
198	3.69
209	3.74
229	3.85
242	3.95
252	4.00

DATA SET 3

T	ρ
3	0.57
15	0.59
31	0.62
46	0.69
62	0.78

DATA SET 3 (cont.)

T	ρ
78	0.89
93	0.95
105	1.06
125	1.17
136	1.22
151	1.31
166	1.39
181	1.47
195	1.55
212	1.65
224	1.73
243	1.84

DATA SET 4

T	ρ
4	0.26
17	0.29
31	0.34
46	0.37
61	0.43
76	0.54
91	0.62
108	0.73
121	0.80
138	0.91
151	0.98
166	1.09
181	1.17
199	1.27
211	1.36
232	1.47

DATA SET 5

T	ρ
1.2	0.11182
2.0	0.11159
2.7	0.11148
3.4	0.11135*
4.2	0.11127

DATA SET 6

T	ρ
1.0	3.926
2.0	3.926
2.8	3.926
3.5	3.926
4.2	3.926

DATA SET 7

T	ρ
1.4	30.790
1.8	30.791
2.2	30.789
2.7	30.789
3.2	30.788
3.7	30.786
4.2	30.785
5.5	30.784
6.0	30.783
7.0	30.780
8.0	30.778
9.1	30.777
10.0	30.776
12.1	30.771
14.1	30.767
16.0	30.764
18.1	30.762
20.2	30.761
22.5	30.761
25.2	30.766
28.1	30.773
29.6	30.781
32.6	30.793
38.2	30.833

DATA SET 8

T	ρ
1.4	15.510
2.1	15.510
2.7	15.510
3.3	15.510
3.9	15.510
4.2	15.509
6.0	15.509
8.0	15.509
10.0	15.509
12.0	15.509
13.9	15.509
16.0	15.510
18.0	15.511
20.2	15.514
22.1	15.516
24.5	15.521
26.0	15.524
29.1	15.534
33.6	15.550
37.7	15.570

DATA SET 9

T	ρ
1.4	15.111
2.1	15.111
2.6	15.111
3.3	15.111
3.9	15.111
5.0	15.110
6.0	15.110
6.9	15.109
8.0	15.109
9.0	15.109
10.0	15.109
12.0	15.109
14.0	15.110
16.0	15.111
18.1	15.112
20.0	15.113
21.3	15.116
24.1	15.121
26.1	15.126
28.7	15.133
32.9	15.148
37.8	15.170
42.4	15.194

DATA SET 10

T	ρ
1.6	11.776
2.4	11.776
3.1	11.775
3.4	11.775
3.9	11.775
4.3	11.775
5.2	11.774
6.0	11.774
7.0	11.774
8.0	11.774
10.1	11.774
12.0	11.774
14.2	11.775
16.2	11.777
18.0	11.778
21.1	11.781
24.2	11.786
29.0	11.800
34.4	11.819
38.6	11.839

DATA SET 11

T	ρ
4.2	4.0
51	4.4
102	4.8
200	5.3
303	6.0
401	6.5
505	7.0
600	7.5
703	8.2
800	8.6
905	9.3
1000	9.9
1103	10.8

DATA SET 12

T	ρ
4.2	8.0
51	8.5
104	8.7
200	9.4
297	10.1
400	10.7
500	11.3
600	11.9
702	12.6
800	12.9
901	13.6
1000	14.3
1102	15.2

DATA SET 13

T	ρ
4.2	12.7
55	13.0
102	13.4
200	14.2
304	14.8
400	15.5
503	16.2
600	16.7
703	17.3
800	17.7
901	18.2
1000	19.0
1106	19.8

DATA SET 14

T	ρ
4.2	17.7
52	18.2
102	18.6
200	19.6
302	20.4
400	21.3
500	22.1
600	22.8
701	23.5
800	24.2
901	25.0
1000	25.9
1103	26.7

DATA SET 15

T	ρ
4.2	24.7
56	25.5
105	26.2
200	27.3
306	28.6
401	29.5
505	30.5
600	31.3
705	32.1
800	32.9
900	33.6
1000	34.0
1105	34.7

DATA SET 16

T	ρ
4.2	0.962
90	1.372
293	2.552

DATA SET 17

T	ρ
4.2	2.28
90	2.68
293	3.87

DATA SET 18

T	ρ
4.2	4.37
90	4.78
293	6.01*

TABLE 66. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF SILVER + PALLADIUM ALLOYS (Temperature Dependence) (continued)

T	ρ
DATA SET 19	
78.2	2.11
198.2	2.87
273.2	3.40
393.2	4.12
534.2	4.92
622.2	5.48
696.2	5.85
767.2	6.35
DATA SET 20	
78.2	1.62
198.2	2.29
273.2	2.80
393.2	3.52
534.2	4.41
622.2	4.94
696.2	5.43
767.2	5.99
DATA SET 21	
78.2	1.12
198.2	1.78
273.2	2.37
393.2	3.09
534.2	3.89
622.2	4.42
696.2	4.94
767.2	5.40
DATA SET 22	
78.2	0.67
198.2	1.56
273.2	1.97
393.2	2.60
534.2	3.45
622.2	3.92
696.2	4.50
767.2	4.97
DATA SET 23	
1.1	27.0196
2.1	27.0183
3.0	27.0178
4.2	27.0162
4.9	27.0163

T	ρ
DATA SET 23 (cont.)	
6.0	27.0151
6.9	27.0141
7.9	27.0127
8.9	27.0113
9.8	27.0107
11.9	27.0084
13.9	27.0077
15.9	27.0055
17.9	27.0058
19.9	27.0062
21.9	27.0093
23.9	27.0132
26.1	27.0194
29.8	27.0341
DATA SET 24	
1.4	21.7803
2.3	21.7796
3.2	21.7792
4.1	21.7785
4.9	21.7785
6.0	21.7774
7.0	21.7774
7.9	21.7773
9.0	21.7766
9.9	21.7773
12.0	21.7760
13.9	21.7770
16.0	21.7781
18.0	21.7812
20.0	21.7837
22.1	21.7878
24.0	21.7922
26.8	21.8004
DATA SET 25	
1.4	17.8402
2.3	17.8398
3.1	17.8398
4.1	17.8398
4.9	17.8398
5.9	17.8386
6.9	17.8386
7.9	17.8386
8.9	17.8386
10.0	17.8388
11.9	17.8388

T	ρ
DATA SET 25 (cont.)	
14.0	17.8391
16.0	17.8396
17.8	17.8420
19.9	17.8438
22.0	17.8479
23.9	17.8520
26.0	17.8584
29.8	17.8712
DATA SET 26	
298	1.90
373	2.38
DATA SET 27	
298	2.05
373	2.55
DATA SET 28	
298	1.96
323	2.17
373	2.42
473	2.97
573	3.55
673	4.10
773	4.55
873	5.17
DATA SET 29	
4.2	1.044
293.2	2.63
DATA SET 30	
4.2	0.925
293.2	2.54*
DATA SET 31*	
4.2	0.94
293.2	2.54
DATA SET 32	
4.2	0.89
293.2	2.52*

T	ρ
DATA SET 33	
4.2	2.21
293.2	3.81*
DATA SET 34*	
4.2	2.20
293.2	3.91
DATA SET 35	
4.2	4.39*
293.2	6.035
DATA SET 36	
4.2	4.15
293.2	6.00*
DATA SET 37	
4.2	8.45
293.2	10.00*
DATA SET 38*	
4.2	8.25
293.2	10.10
DATA SET 39	
4.2	12.86*
293.2	14.55
DATA SET 40*	
4.2	12.78
293.2	14.66
DATA SET 41	
4.2	19.16
32.0	19.20
40.3	19.25
55.8	19.34
61.4	19.39
73.5	19.48
78.7	19.56
87.1	19.65
104.2	19.81

T	ρ
DATA SET 41 (cont.)	
140.3	20.11
177.4	20.45
263.6	21.17
300.0	21.44
DATA SET 42	
4.2	18.10
293.2	21.1
DATA SET 43	
4.2	29.88
40.9	30.02
59.0	30.19
61.5	30.23
70.6	30.36
79.8	30.48
89.3	30.64
97.9	30.75
114.3	30.98
150.3	31.39
167.1	31.66
222.8	32.28
272.3	32.65
303.4	33.03
DATA SET 44	
4.2	27.7
293.2	30.5
DATA SET 45	
4.23	0.4720
4.23	0.4720*
4.23	0.4720*
4.95	0.4720
5.73	0.4721
6.68	0.4721
7.10	0.4721
7.57	0.4722
8.28	0.4722
9.64	0.4724
10.87	0.4727
11.83	0.4729
12.74	0.4732
13.55	0.4736
14.56	0.4743

T	ρ
DATA SET 45 (cont.)	
14.56	0.4743*
16.33	0.4757
17.66	0.4771
18.16	0.4777
19.37	0.4793
DATA SET 46	
6.79	0.4001
7.26	0.4001
7.62	0.4002
8.95	0.4003
9.77	0.4004
10.59	0.4006
11.70	0.4009
13.27	0.4015
14.39	0.4021
15.35	0.4029
15.35	0.4028*
16.41	0.4036
17.22	0.4045
19.32	0.4071
DATA SET 47	
4.23	0.2900
4.23	0.2900*
4.23	0.2900*
4.55	0.2900
4.91	0.2900
5.68	0.2900
6.59	0.2901
7.03	0.2901
7.55	0.2901
8.05	0.2902
8.71	0.2903
9.57	0.2904
10.72	0.2904
11.75	0.2908
12.56	0.2911
13.55	0.2915
14.46	0.2920
15.14	0.2925
16.37	0.2935
17.62	0.2946
18.37	0.2953*
18.45	0.2955
19.37	0.2968

* Not shown in figure.

TABLE 66. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF SILVER + PALLADIUM ALLOYS (Temperature Dependence) (continued)

DATA SET 48*

T	ρ
4.34	0.04221
4.67	0.04222
4.84	0.04222
5.26	0.04223
5.47	0.04223
5.88	0.04225
6.18	0.04225
6.55	0.04227
6.93	0.04229
7.35	0.04232
7.57	0.04234
8.55	0.04240
9.08	0.04246
10.30	0.04266
11.14	0.04282
12.08	0.04306
13.37	0.04343
14.26	0.04383
15.45	0.04443
16.41	0.04508
17.54	0.04593
18.58	0.04686
19.77	0.04797

DATA SET 49*

T	ρ
4.70	0.04152
4.89	0.04152
5.27	0.04153
5.52	0.04153
5.94	0.04155
6.27	0.04156
6.64	0.04157
7.02	0.04159
7.41	0.04162
7.71	0.04164
8.61	0.04170
9.23	0.04177
10.28	0.04195
11.17	0.04211
12.16	0.04234
13.34	0.04269
14.32	0.04311
15.45	0.04368
16.44	0.04434
17.54	0.04516
18.62	0.04610
19.82	0.04723

DATA SET 50*

T	ρ
2.11	0.006070
2.11	0.006070
2.36	0.006071
2.36	0.006071
2.57	0.006071
2.76	0.006071
2.96	0.006072
3.18	0.006072
3.38	0.006073
3.59	0.006074
3.78	0.006074
3.99	0.006076
4.24	0.006077
4.29	0.006078
5.11	0.006087
6.11	0.006106
6.58	0.006121
7.15	0.006138
7.85	0.006168
8.00	0.006175
8.81	0.006231
9.57	0.006284
10.28	0.006366
10.69	0.006411
10.87	0.006437
12.13	0.006635
13.00	0.006820
13.65	0.006955
14.76	0.007287
15.24	0.007476
15.78	0.007652
16.22	0.007911
16.52	0.008038
16.94	0.008263
17.91	0.008825
18.97	0.009554
19.54	0.009998

DATA SET 51

T	ρ
91	13.797
173	14.256
193	14.482
274	14.965
293	14.984
373	15.409

DATA SET 52

T	ρ
1.7	28.8455
2.1	28.8452
3.0	28.8449
3.6	28.8444
4.1	28.8436
5.4	28.8418
5.9	28.8411
6.8	28.8397
7.9	28.8380
9.0	28.8363
10.3	28.8341
13.1	28.8298
15.0	28.8274
16.2	28.8261
17.9	28.8253
19.1	28.8251
20.1	28.8253
21.6	28.8263
23.0	28.8281

DATA SET 53

T	ρ
1.5	18.4114
1.9	18.4120
2.5	18.4135
3.1	18.4148
3.8	18.4169
4.3	18.4191
4.8	18.4217
5.5	18.4251
5.9	18.4291
6.8	18.4371
8.1	18.4525

DATA SET 54

T	ρ
1.6	13.1317
2.2	13.1325
2.9	13.1338
3.9	13.1358
4.3	13.1372
4.7	13.1381
5.1	13.1396
6.1	13.1443
6.6	13.1476
7.3	13.1526
8.5	13.1636
9.6	13.1758
10.2	13.1838

DATA SET 55

T	ρ
1.5	8.68269
2.0	8.68275
2.5	8.68281
3.3	8.68298
3.7	8.68307
4.0	8.68317

DATA SET 56

T	ρ
1.4	3.25270
2.1	3.25270
2.7	3.25270
3.3	3.25275
4.2	3.25279

DATA SET 57

T	ρ
301	31.97
312	32.19*
347	32.69
382	33.29
444	34.21
520	35.40
557	35.91*
576	36.21
608	36.61*
632	36.97*
662	37.37
691	37.76*
714	38.01*
742	38.36
762	38.61*
777	38.75*
791	38.94*
801	39.06*
814	39.19*
851	39.53
875	39.74*
884	39.85*
896	39.94

DATA SET 58*

T	$\rho(T)/\rho(298)$
315	1.0128
347	1.0230
373	1.0335
410	1.0479
452	1.0576
475	1.0715
522	1.0815
536	1.0894
634	1.1249
722	1.1602
760	1.1692
794	1.1846
864	1.2063
949	1.2269
1020	1.2485

DATA SET 59*

T	$\rho(T)/\rho(298)$
342	1.0182
393	1.0355
420	1.0457
459	1.0536
487	1.0695
553	1.0875
575	1.0913
607	1.1038
720	1.1377
736	1.1402
787	1.1605
861	1.1881
882	1.1889
945	1.2110
994	1.2222
1006	1.2373

DATA SET 60*

T	$\rho(T)/\rho(298)$
342	1.0145
361	1.0219
391	1.0287
431	1.0375
457	1.0488
527	1.0636
561	1.0778

DATA SET 60 (cont.)*

T	$\rho(T)/\rho(298)$
582	1.0824
601	1.0832
617	1.0896
695	1.0987
762	1.1022
813	1.1039
848	1.1024
865	1.1022
937	1.1057
962	1.1116
999	1.1160
1033	1.1168
1048	1.1168
1075	1.1243
1149	1.1328

DATA SET 61*

T	$\rho(T)/\rho(298)$
297	1.0039
310	1.0061
331	1.0103
362	1.0166
400	1.0242
435	1.0323
493	1.0424
549	1.0530
574	1.0610
585	1.0627
605	1.0627
647	1.0720
688	1.0733
731	1.0757
801	1.0865
861	1.0981
908	1.1062
930	1.1087
1021	1.1282
1105	1.1426
1173	1.1544

* Not shown in figure.

TABLE 67. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + SILVER ALLOYS (Temperature Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Pd	Ag	Composition (continued), Specifications, and Remarks
1	45	Coles, B.R. and Taylor, J.C.	1962	A	77-393			39.3	Calculated composition (39.0 a/o Ag), composition determined by chemical analysis, spectrographic analysis of a few samples showed no abnormal incidence of impurities; 1.524 mm (0.060 in.) wire specimen; supplied by Precious Metals Division of Mond Nickel Co. prepared from 99.95$^+$ pure metals by melting in argon atmosphere; annealed in vacuum at 1023 to 1173 K; ρ_0 = 40.2 x 10^{-8} Ωm, dρ/dT = 0.0037 x 10^{-8} Ωm K^{-1} at 293 K; ±1% uncertainty in cross-sectional area; data read from figure.
2	387	Sarachik, M.P.	1968	A	1.7-40		74.4	25.1	0.5 Fe; calculated composition (Pd_3Ag + 1 a/o Fe); ±10% error arises from sample geometry and composition; data read from figure.
3	378	Ricker, T. and Pflüger, E.	1966	B	4.2-1102		89.9		Calculated composition (90 a/o Pd); 0.35 to 0.5 mm in diameter and 50 to 100 cm long; supplied by Firma Degussa; prepared from 99.9 pure palladium and 99.99 pure silver; annealed in argon at 1073 K for 30 min and quenched in water; data read from figure.
4	378	Ricker, T. and Pflüger, E.	1966	B	4.2-1100		79.8		Calculated composition (80 a/o Pd); similar to the above specimen.
5	378	Ricker, T. and Pflüger, E.	1966	B	4.2-1099		69.7		Calculated composition (70 a/o Pd); similar to the above specimen.
6	378	Ricker, T. and Pflüger, E.	1966	B	4.2-1101		59.7		Calculated composition (60 a/o Pd); similar to the above specimen.
7	380	Edwards, L.R., Chen, C.W., and Legvold, S.	1970		1.7-26			25.26	Calculated composition (25 a/o Ag), 0.0050-0.0250 wt.% Fe present; authors concluded minimum in resistivity was not due to Fe; data read from figure.
8	380	Edwards, L.R., et al.	1970		1.5-30			40.33	Calculated composition (40 a/o Ag); similar to the above specimen.
9	380	Edwards, L.R., et al.	1970		1.9-30			43.34	Calculated composition (43 a/o Ag); similar to the above specimen.
10	380	Edwards, L.R., et al.	1970		1.4-34			45.34	Calculated composition (45 a/o Ag); similar to the above specimen.
11	284	Köster, W. and Hagmann, D.	1961		298.2			2.03	Calculated composition (2 a/o Ag); 1 mm wire specimen supplied by Firma Degussa; annealed at 1073 K for 1 h and furnace-cooled; data extracted from table.
12	284	Köster, W. and Hagmann, D.	1961		298.2			4.05	Calculated composition (4 a/o Ag); similar to the above specimen.
13	376	Kemp, W.R.G., Klemens, P.G., Sreedhar, A.K., and White, G.K.	1956	B	4.2-303		50	50	Wire specimen; supplied by Johnson, Matthey and Co.; annealed at 1153 and 773 K; data read from figure.
14	376	Kemp, W.R.G., et al.	1956		4.2,293		50	50	Rod specimen; supplied by Johnson, Matthey and Co.; annealed at 1153 K; measured with aid of galvanometer amplifier; data extracted from table.
15	376	Kemp, W.R.G., et al.	1956	B	4.2-305		70	30	Wire specimen; supplied by Johnson, Matthey and Co.; annealed at 1153 and 773 K; data read from figure.
16	376	Kemp, W.R.G., et al.	1956		4.2,293		70	30	Rod specimen; supplied by Johnson, Matthey and Co.; annealed at 1153 K; measured with aid of galvanometer amplifier; data extracted from table.

TABLE 67. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + SILVER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Pd	Ag	Composition (continued), Specifications, and Remarks
17	376	Kemp, W.R.G., Klemens, P.G., Sreedhar, A.K., and White, G.K.	1956	B	4.2-293		95	5	Wire specimen; supplied by Johnson, Matthey and Co.; annealed at 1153 and 773 K; data read from figure.
18	376	Kemp, W.R.G., et al.	1956		4.2, 293		95	5	Rod specimen: supplied by Johnson, Matthey and Co.; annealed at 1153 K.
19	379	Murani, A.P.	1974		1.7-9.9			8.1	Calculated composition (8 a/o Ag); preliminary results with no measurement information; data read from figure.
20	379	Murani, A.P.	1974		1.6-12.7			19.2	Calculated composition (19 a/o Ag); similar to the above specimen.
21	379	Murani, A.P.	1974		1.7-21.1			33.3	Calculated composition (33 a/o Ag); similar to the above specimen.
22	175	Ahmad, H.M. and Greig, D.	1974		6-911			40.3	Calculated composition (40 a/o Ag); no measurement information; data read from figure.
23	382	Greig, D. and Rowlands, J.A.	1974	A	1.5-6.9			0.51	Calculated composition (0.5 a/o Ag), composition determined by weighing component metals; Pd with less than 0.001 wt.% metallic impurities from Englehard Industries and Ag from Johnson-Matthey Ltd. melted together in argon arc furnace which had tungsten electrode, copper hearth, and titanium getter; cooled into form of a 'button' which was turned over and remelted 5 times to ensure mixing, pressed, rolled, and swaged into 2 mm diam rods about 12 cm long, annealed for 24 h at 1123 K in a vacuum furnace, and cooled slowly; error in geometrical factor ±0.1%, temperature steady to ±5 mK and measured to ±100 mK, smallest resistivity measurable was 1 pΩm; measured resistivity ρ analyzed as $\rho = \rho_0 + \rho_T$ where the residual resistivity ρ_0 was determined by assuming the temperature dependent $\rho_T = AT^2$ and making a best fit to the experimental data, ρ_0 was 0.512×10^{-8} Ωm; data reported in figure in the form of ρ_T.
24	383	Greig, D. and Rowlands, J.A.	1974		1.3-273.0			0.51	Calculated composition (0.5 a/o Ag), composition determined by weighing components; Pd from Englehard Industries and Ag from Johnson-Matthey melted into a 'button' in argon arc furnace, homogenized by turning over and remelting 5 times, pressed, rolled, and swaged into rod 2 mm in diam and 12 cm long, annealed in vacuum for 24 h at 1123 K; geometrical factor known to ±0.1%, temperatures to ±0.1 K; measured in same run as two following specimens, temperature difference between specimens less than 0.001 K; within accuracy of measurements, the 1.3 K value may be taken as the residual resistivity; data extracted from table.
25	383	Greig, D. and Rowlands, J.A.	1974		1.3-273.0			1.0	Calculated composition (1 a/o Ag); similar to the above specimen.
26	383	Greig, D. and Rowlands, J.A.	1974		1.3-273.0			2.0	Calculated composition (2 a/o Ag); similar to the above specimen.

TABLE 67. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + SILVER ALLOYS (Temperature Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp. Range, K	Name and Specimen Designation	Composition (weight percent) Pd	Ag	Composition (continued), Specifications, and Remarks
27	384	Arajs, S., Rao, K. V. Yao, Y. D. and Teoh, W.	1977	A	301-891			44.64	Calculated composition (44.3 a/o Ag); 99.99 pure Pd sponge from Engelhard Industries Inc. and 99.999 pure Ag from American Smelting and Refining Co. arc-melted to form ingot weighing about 10 g; ingot sealed in evacuated silica tube, homogenized at about 1300 K for 60 h, drawn to 1 mm² cross-section, cleaned, re-sealed in evacuated silica capsule, annealed at 1200 K for 1 h, and rapidly cooled in air without breaking the capsule; measurement temperatures produced by platinum-wound vacuum furnace; data read from figure.
28	384	Arajs, S., et al.	1977	A	302-889			40.33	Calculated composition (40.0 a/o Ag); similar to the above specimen.
29	384	Arajs, S., et al.	1977	A	302-892			35.11	Calculated composition (34.8 a/o Ag); similar to the above specimen.
30	384	Arajs, S., et al.	1977	A	300-890			30.29	Calculated composition (30.0 a/o Ag); similar to the above specimen.
31	384	Arajs, S., et al.	1977	A	300-900			40.33	Calculated composition (40.0 a/o Ag); similar to the above specimen but cold-worked to show different temperature dependence of the resistivity.
32*	369	Pravoverov, N. L., and Savitskii, E. M.	1962	A	327-708	1		15.2	Calculated composition (15 a/o Ag); 10 g charge melted under borax in induction furnace, cast, forged, rolled, and vacuum annealed for 120 h at 1273 K and 250 h at 1073 K in order to bring nearly to equilibrium; annealed as 1 mm diam wire, then drawn down to 0.3 mm diam and again annealed for 1 h at 1173 K to remove work-hardening; sample specimen consisted of 250 mm of the wire wound into cylindrical coil of mean diam 3 mm and length 25 mm; coil welded to junctions of two thermocouples consisting of Pt and Pt-Rh; Pt electrodes formed part of the current-supplying circuit and Pt-Rh ones part of the current-removing circuit; recorded temperature was mean of values for the two thermocouples, with no significant temperature drop along the length of the coil; direction of the specimen current reversed and mean resistivity recorded; data reported as $\rho(T)/\rho(298)$, the ratio of the resistivity at the measurement temperature (T) to that at 298 K, without reporting $\rho(298)$; data read from figure.
33*	369	Pravoverov, N. L., and Savitskii, E. M.	1962	A	354-1186	7		35.3	Calculated composition (35 a/o Ag); similar to the above specimen.
34*	369	Pravoverov, N. L., and Savitskii, E. M.	1962	A	293-875	2		40.3	Calculated composition (40 a/o Ag); similar to the above specimen.
35*	369	Pravoverov, N. L., and Savitskii, E. M.	1962	A	303-1024	8		45.3	Calculated composition (45 a/o Ag); similar to the above specimen.

* Not shown in figure.

TABLE 68. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + SILVER ALLOYS (Temperature Dependence)

[Temperature, T, K; Electrical Resistivity, ρ, $10^{-8}\ \Omega m$]

T	ρ
DATA SET 1	
77	41.0
90	41.3
194	42.4
272	42.8
295	42.8
322	42.9
334	42.9
348	42.9
361	42.9
378	42.8
393	42.8
DATA SET 2	
1.7	32.06
2.3	32.07
3.2	32.08
4.3	32.10
5.2	32.12
6.3	32.13
7.2	32.13
8.3	32.14
9.3	32.14
10.2	32.14
12.2	32.15
14.3	32.15
16.2	32.15
18.2	32.16
20.2	32.16
22.2	32.17
24.3	32.18
26.2	32.20
28.2	32.22
30.3	32.24
32.3	32.27
34.3	32.30
36.3	32.33
38.4	32.37
40.0	32.40
DATA SET 3	
4.2	12.4
49	14.2
100	16.2
200	20.1
DATA SET 3 (cont.)	
302	23.7
400	26.7
498	29.9
600	32.8
692	35.3
800	37.7
898	39.9
1000	41.7
1102	43.3
DATA SET 4	
4.2	24.6
50	26.4
103	28.4
201	31.3
299	33.9
400	35.9
497	37.6
600	39.2
701	40.5
800	41.6
898	43.0
1000	43.8
1100	44.8
DATA SET 5	
4.2	35.6
53	37.0
100	38.4
200	40.4
303	41.8
400	42.8
501	43.6
600	44.2
699	44.7
800	45.2
902	45.6
1000	46.0
1099	46.4
DATA SET 6	
4.2	40.0
55	40.7
DATA SET 6 (cont.)	
104	41.4
200	42.3
254	42.4
300	42.6*
400	42.1*
500	41.8
600	42.0
702	42.3
800	42.5
901	42.9*
1000	43.1*
1101	43.6*
DATA SET 7	
1.7	30.2983
2.3	30.2976
3.2	30.2972
4.1	30.2965
4.9	30.2954
5.9	30.2946
6.8	30.2934
7.9	30.2929
8.9	30.2930
9.9	30.2930
11.9	30.2912
13.9	30.2915
15.9	30.2924
17.9	30.2971
19.9	30.3028
22.0	30.3134
24.0	30.3292
26.1	30.3455
DATA SET 8	
1.5	39.3109
2.3	39.3101
3.3	39.3091
4.1	39.3082
4.9	39.3079
5.9	39.3065
6.9	39.3021
7.9	39.3002
9.0	39.2978
9.9	39.2961
DATA SET 8 (cont.)	
11.9	39.2919
13.9	39.2887
15.8	39.2851
17.9	39.2817
20.0	39.2799
21.9	39.2806
23.8	39.2840
26.0	39.2898
29.8	39.3066
DATA SET 9	
1.9	38.4424
3.4	38.4406
4.0	38.4399
5.0	38.4378
5.9	38.4358
7.0	38.4339
7.9	38.4319
9.0	38.4291
10.0	38.4266
11.9	38.4209
13.9	38.4155
15.9	38.4114
17.9	38.4073
20.0	38.4044
22.0	38.4058
23.6	38.4062
26.2	38.4110
28.1	38.4201
30.1	38.4298
DATA SET 10	
1.4	35.5448
2.4	35.5448
3.2	35.5438
4.0	35.5445
4.9	35.5419
6.0	35.5439
6.9	35.5428
7.9	35.5396
8.9	35.5376
9.9	35.5348
11.9	35.5318
14.0	35.5269
DATA SET 10 (cont.)	
16.0	35.5210
17.9	35.5181
20.0	35.5159
22.0	35.5144
24.0	35.5155
25.9	35.5155
28.9	35.5253
33.5	35.5466
DATA SET 11	
298	11.8
DATA SET 12	
298	13.3
DATA SET 13	
4.2	29.88
40.9	30.02
59.0	30.19
61.5	30.23
70.6	30.36
79.8	30.48
89.3	30.64
97.9	30.75
114.3	30.98
150.3	31.39
167.1	31.66
222.8	32.28
272.3	32.65
303.4	33.03
DATA SET 14	
4.2	27.7
293.2	30.5
DATA SET 15	
4.2	35.6*
32.9	35.7*
40.7	35.8
60.1	36.2
62.8	36.2
DATA SET 15 (cont.)	
71.0	36.5
80.5	36.7
89.7	37.0
98.4	37.2
114.6	37.6
151.0	38.5
161.1	38.7
224.4	39.8
275.4	40.6
304.8	40.9*
DATA SET 16	
4.2	35.6*
293.2	40.9
DATA SET 17	
4.2	6.61
6.67	6.61
8.89	6.61
11.1	6.62
13.0	6.62
14.5	6.62
17.7	6.64
21.8	6.67
29.0	6.75
33.8	6.84
41.6	7.04
57.5	7.50
62.8	7.73
73.5	8.11
83.0	8.50
92.5	9.03
109.6	9.77
145.2	11.21
186.2	12.78
274.8	16.18
293.2	17.2
DATA SET 18	
4.2	5.81
293.2	16.8

* Not shown in figure.

TABLE 68. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + SILVER ALLOYS (Temperature Dependence) (continued)

DATA SET 19

T	ρ
1.7	11.48666
2.4	11.48669
3.1	11.48679
3.7	11.48688
4.5	11.48704
5.2	11.48713
5.8	11.48736
6.5	11.48768
7.5	11.48831
8.7	11.48915
9.9	11.48057

DATA SET 20

T	ρ
1.6	24.33506
1.9	24.33489
2.2	24.33476
2.9	24.33473
3.6	24.33450
4.0	24.33445
4.5	24.33442
4.7	24.33401
5.3	24.33393
5.8	24.33385
6.4	24.33371
7.6	24.33373
8.8	24.33391
10.1	24.33448
11.3	24.33549
12.7	24.33722

DATA SET 21

T	ρ
1.7	37.9285
2.1	37.9290
2.7	37.9272
3.6	37.9261
4.4	37.9251
4.6	37.9240
5.1	37.9234*
5.5	37.9222
6.6	37.9202
7.3	37.9189*
8.6	37.9166*
9.7	37.9145
10.2	37.9134*
10.9	37.9117
12.2	37.9091*

DATA SET 21 (cont.)

T	ρ
13.3	37.9074
14.6	37.9049
15.6	37.9040
16.2	37.9036*
16.9	37.9032
17.5	37.9032
19.2	37.9031
20.0	37.9040*
20.4	37.9046*
21.1	37.9057

DATA SET 22

T	ρ
6	39.564
17	39.522*
25	39.546*
32	39.588*
40	39.672
50	39.821*
60	40.022
71	40.180*
80	40.333*
91	40.486*
100	40.663
110	40.825*
119	40.948*
129	41.084
139	41.208*
148	41.307*
159	41.396*
179	41.571*
198	41.711*
218	41.830
238	41.924*
257	41.995*
276	42.038
290	42.065*
310	42.086*
328	42.105*
350	42.115*
368	42.121
389	42.117*
407	42.114*
428	42.105*
453	42.089*
469	42.078*
490	42.061*
510	42.051*

DATA SET 22 (cont.)

T	ρ
530	42.033*
548	42.019*
566	42.004*
586	41.994*
607	41.978*
624	41.964*
649	41.944*
666	41.933*
688	41.922*
709	41.922*
727	41.935
748	41.957*
766	41.974*
783	41.990*
807	42.010*
828	42.027*
848	42.047
867	42.068*
888	42.088*
911	42.120

DATA SET 23

T	ρ
1.51	0.51205
2.00	0.51209
3.01	0.51221
4.00	0.51245
4.98	0.51263
5.97	0.51295
6.90	0.51319

DATA SET 24

T	ρ
1.3	0.512
19.8	0.5527
25.0	0.5996
30.1	0.6668
40.0	0.8733
66.0	1.713
79.7	2.292
103.7	3.339
199.0	7.120
273.0	10.308

DATA SET 25

T	ρ
1.3	1.066
19.8	1.1089

DATA SET 25 (cont.)

T	ρ
25.0	1.1593
30.1	1.2318
40.0	1.4516
66.0	2.315
79.7	2.896
103.7	3.946
199.0	7.726
273.0	10.902

DATA SET 26

T	ρ
1.3	1.877
19.8	1.9213
25.0	1.9753
30.1	2.0528
40.0	2.2855
66.0	3.177
79.7	3.764
103.7	4.817
199.0	8.584
273.0	11.738

DATA SET 27

T	ρ
301	41.15*
338	41.86
364	42.34*
413	43.26
438	43.68*
487	44.58
522	45.11
582	45.95
617	46.42*
654	46.87
710	47.44*
784	47.96
801	48.07*
829	48.22*
862	48.41*
891	48.49

DATA SET 28

T	ρ
302	44.77
338	45.40
364	45.85*
413	46.68
438	47.10
488	47.93
524	48.48*

DATA SET 28 (cont.)

T	ρ
581	49.30
614	49.73*
652	50.18
710	50.75*
783	51.35
799	51.44*
828	51.51*
859	51.71*
889	51.77

DATA SET 29

T	ρ
302	43.67
338	44.43
362	44.90
413	45.88*
439	46.36
489	47.28
523	47.84
580	48.70*
615	49.16
653	49.62*
709	50.24
782	50.81*
800	50.91
828	51.09
860	51.25
892	51.30*

DATA SET 30

T	ρ
300	40.33
337	40.66
362	41.25*
413	42.55
440	43.17
489	44.33*
525	45.26*
581	46.48
615	47.13*
652	47.80
709	48.84*
782	49.96
798	50.14*
828	50.49*
859	50.86*
890	51.10*

DATA SET 31

T	ρ
300	45.42
350	45.95
400	46.38
450	46.81
500	47.26
550	47.65
600	48.02
650	48.29*
700	48.55
750	48.75*
800	48.93*
850	49.07
900	49.20

DATA SET 32*

T	$\frac{\rho(T)}{\rho(298)}$
327	1.0066
371	1.0260
418	1.0617
481	1.0983
547	1.1316
614	1.1819
699	1.2268
708	1.2424

DATA SET 33*

T	$\frac{\rho(T)}{\rho(298)}$
354	1.0033
395	1.0109
451	1.0163
484	1.0222
513	1.0275
552	1.0296
590	1.0342
641	1.0370
735	1.0452
821	1.0502
846	1.0519
907	1.0601
1053	1.0734
1133	1.0805
1186	1.0853

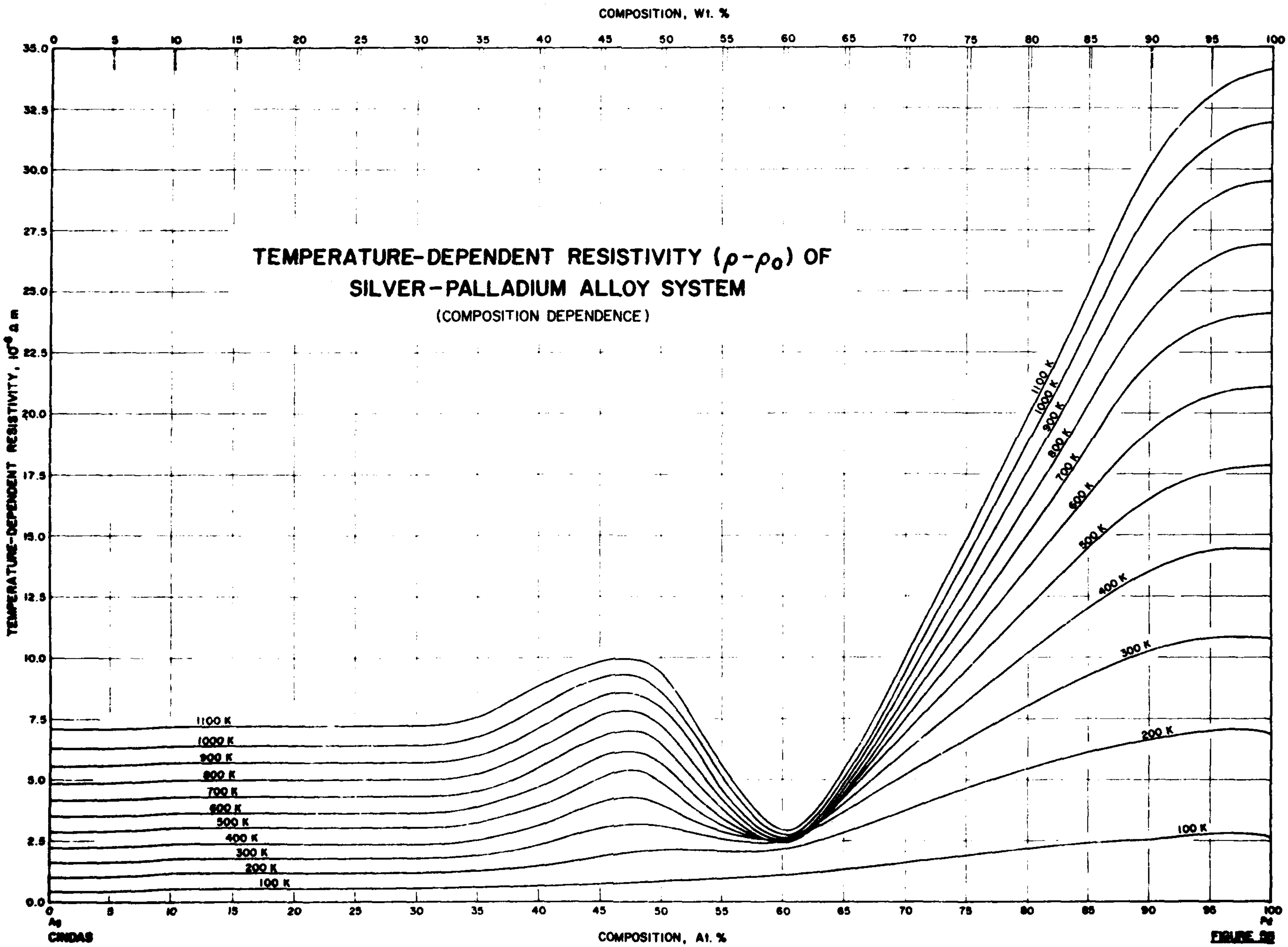
* Not shown in figure.

TABLE 68. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF PALLADIUM + SILVER ALLOYS (Temperature Dependence) (continued)

T	$\frac{\rho(T)}{\rho(298)}$
DATA SET 34*	
293	1.0027
313	1.0026
356	1.0069
378	1.0212
410	1.0424
428	1.0578
456	1.0681
524	1.1081
586	1.1427
729	1.1894
743	1.2081
835	1.2326
875	1.2481

T	$\frac{\rho(T)}{\rho(298)}$
DATA SET 35*	
303	1.0017
315	1.0010
335	1.0015
369	1.0063
390	1.0078
419	1.0095
452	1.0104
491	1.0157
518	1.0175
553	1.0195
575	1.0185
608	1.0187
616	1.0206
691	1.0221
775	1.0242
843	1.0223
912	1.0278
963	1.0282
992	1.0309
1084	1.0291

* Not shown in figure.


TEMPERATURE-DEPENDENT RESISTIVITY ($\rho-\rho_0$) OF
SILVER-PALLADIUM ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION, Wt. %
COMPOSITION, At. %
TEMPERATURE-DEPENDENT RESISTIVITY, $10^{-8}\ \Omega\ m$
Ag
Pd
CINDAS
1100 K
1000 K
900 K
800 K
700 K
600 K
500 K
400 K
300 K
200 K
100 K

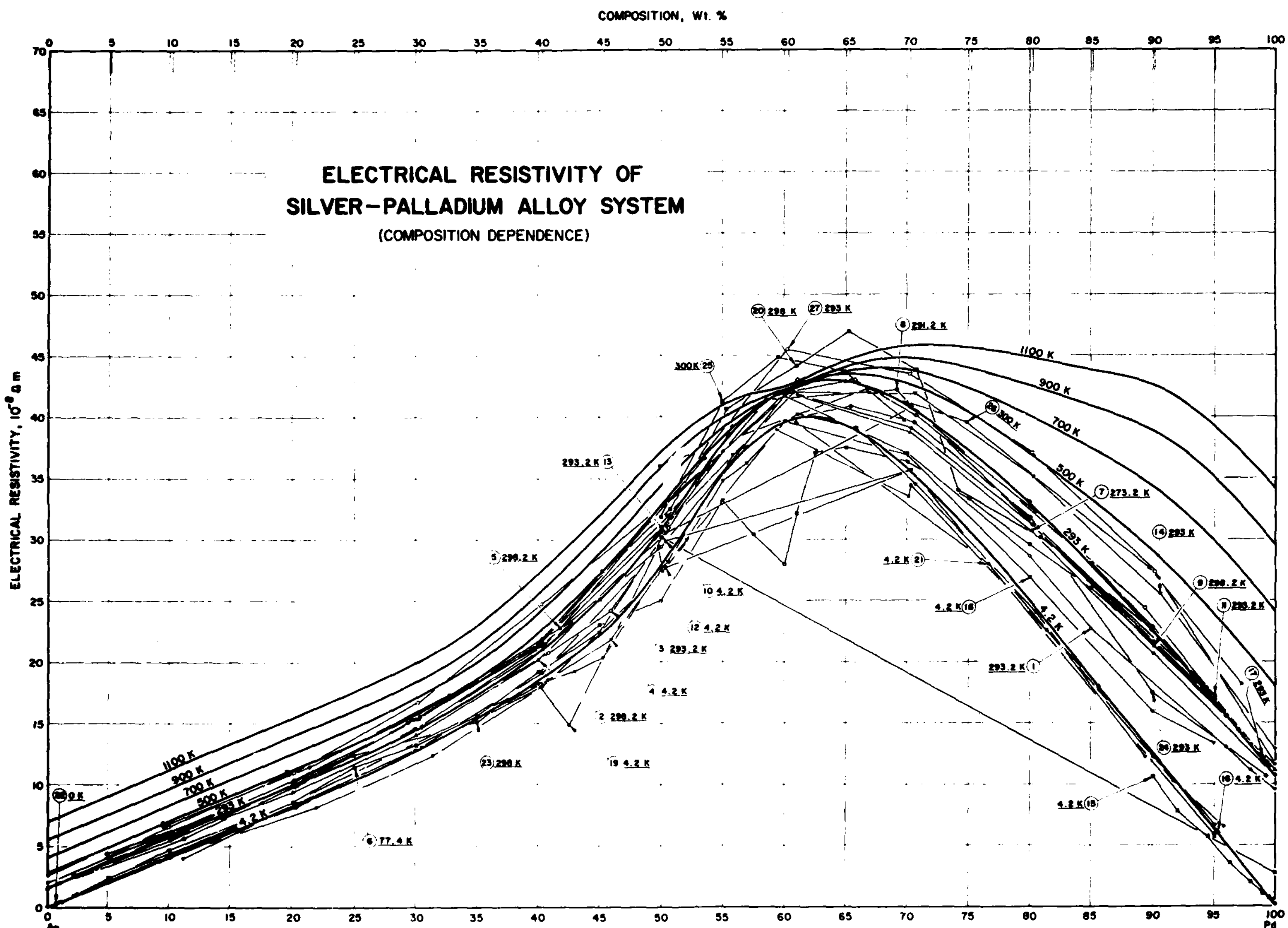

ELECTRICAL RESISTIVITY OF
SILVER-PALLADIUM ALLOY SYSTEM
(COMPOSITION DEPENDENCE)
COMPOSITION, Wt. %
COMPOSITION, At. %
ELECTRICAL RESISTIVITY, $10^{-8}\ \Omega\ m$
Ag
Pd
1100 K
900 K
700 K
500 K
293 K
4.2 K
CINDAS

FIGURE 36

TABLE 69. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM (Composition Dependence)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Pd)	Composition (weight percent), Specifications, and Remarks
1	312	Ricker, T.	1963	V	293.2	1-100	Compositions determined by chemical analysis; specimens prepared from 99.99 pure metals by arc-melting in inert gas; ingots homogenized and rolled to 0.1 mm thick; annealed at 1073 K for 1 h and air cooled; data extracted from table.
2	388	Seeman, H.J. and Rennollet, G.	1966	A	298.2	0-100	Prepared by melting in argon; rolled to 0.7 mm thick, annealed in vacuum at 1073 K for 30 min, rolled to 0.2 mm thick, and finally rolled to 0.1 mm thick after repeated annealing in vacuum; data extracted from table.
3	45	Coles, B.R. and Taylor, J.C.	1962	A	293.2	0-100	Compositions determined by chemical analysis, spectrographic analysis of selected samples showed no abnormal incidence of impurities; wire specimens 1.524 mm (0.060 in) in diam supplied by Precious Metals Division of Mond Nickel Co.; prepared from 99.95+ pure metals by melting in argon; annealed in vacuum at 1023 to 1173 K; temperature coefficients of resistivity also reported; ± 1% uncertainty in cross-sectional area; temperature-dependent resistivities read from figure and added to residual resistivities of the following curve.
4	45	Coles, B.R. and Taylor, J.C.	1962	A	4.2	11.1-89.4	The above specimens; data read from figure.
5	373	Westerlund, R.W. and Nicholson, M.E.	1966	P	298	9.53-53.53	Compositions determined by gravimetric analysis; prepared from American Platinum Co. 99.99 pure silver and Englehard Industries Inc. 99.9 pure palladium by induction melting under vacuum in recrystallized alumina crucibles, homogenizing in vacuum of 5×10^{-5} mm Hg at 1223 K for 1 week, cold-reducing, annealing in vacuum at 873 K for 2 h, and cold-rolling to 0.002 in thick; measured in annealed state in an oil bath maintained at 298 ± 3 K; specimen thickness determined using linear x-ray absorption; data read from figure.
6	370	Aarts, W.H. and Houston-MacMillan, A.S.	1957		77.4	5-100	Wire specimens of about 0.3 mm diam; palladium from Pure Metals Division of Mond Nickel Co.; measured in liquid nitrogen bath; standard deviations from the measured resistivities of the 5, 10, 20, 25, 30, 35, 40, 45, 50, and 100 a/o Pd samples were 0.01, 0.04, 0.03, 0.28, 0.04, 0.24, 1.13, 0.17, 1.9, and $0.01 \times 10^{-8}\ \Omega$m, respectively; data extracted from table.
7	389	Geibel, W.	1911		273.2	0-100	Wire specimens of 0.1 mm diam; data extracted from table.
8	221	Svensson, B.	1932	B	291.2	0-100	Specimens 1 mm square and 42 mm long; prepared from Heraeus physically pure palladium and Hilger spectroscopically pure silver; annealed at 1273 to 1323 K for 10 to 12 h; data extracted from table.
9	286	Schulze, F.A.	1911		248.2	0-100	Wire specimens of 1 mm diam supplied by Firma Heraeus; data extracted from table.
10	376	Kemp, W.R.G., Klemens, P.G., Sreedhar, A.K., and White, G.K.	1956	B	4.2	2.11-95.06	Wire specimens supplied by Johnson, Matthey and Co.; 2.11 and 5.13 a/o Pd samples wound on mica former and annealed at 883 K; 10.02, 20.30, and 29.91 a/o Pd samples wound on mica former and annealed at 923 K; remaining samples annealed at 1153 K, wound on mica former, and reannealed at 773 K; data extracted from table.
11	376	Kemp, W.R.G., et al.	1956	B	293.2	2.11-95.06	The above specimens.
12	376	Kemp, W.R.G., et al.	1956	B	4.2	2.11-95.06	Rod specimens supplied by Johnson, Matthey and Co.; 2.11 and 5.13 a/o Pd samples annealed at 883 K; 10.02 a/o Pd sample annealed at 923 K; 20.30 and 29.91 a/o Pd samples annealed at 1073 K; remaining samples annealed at 1153 K; data extracted from table.
13	376	Kemp, W.R.G., et al.	1956	B	293.2	2.11-95.06	The above specimens.

TABLE 69. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Pd)	Composition (weight percent), Specifications, and Remarks
14	287	Rudnitskii, A.A.	1956		293	0-100	Manufactured in high-frequency furnace, drawn to 0.5 mm diam wire, annealed at 973 to 1073 K for 7 d; measurement temperature not stated explicitly, assumed to be 293 K; data read from figure; original work by Nemilov, V.A., Rudnitskii, A.A., and Vidusova, T.A. (Izv. Sektora platiny, 20, 225, 1946) but this document unavailable.
15	390	Greig, D. and Livesey, D.	1972	A	4.2	90.05-99.95	Foil specimens about 0.3 mm thick prepared by M.J. Walker, University of Leeds using Pd from Johnson, Matthey and Co. Ltd.; constituents melted in argon arc-furnace, formed into 'button' ingots, cold-rolled between plastic sheets, annealed at 1173 K for at least 16 h in sealed evacuated quartz tubes, and cooled at about 1 K min^{-1}; Hall coefficients at 4.2 K and room temperature also reported; residual resistivity obtained from resistance ratio by method which assumes Matthiessen's rule, with the fractional error in ρ_0 the same as the fractional deviation from the rule at room temperature; measured ratios of resistance at room temperature to resistance at 4.2 K were 1.99, 2.36, 2.87, 4.03, 6.42, 10.0, 16.4, 22.1, 46.7, and 81.5 for the 90.05, 92, 94.44, 96.3, 98, 99.01, 99.52, 99.75, 99.9 and 99.95 a/o Pd alloys respectively; data extracted from table.
16	32	Fletcher, R. and Greig, D.	1967	A	4.2	90.27, 95.22	Compositions determined by chemical analysis; prepared by International Nickel Ltd., annealed at 973 K for 24 h, outgassed 4 to 5 h at 773 K; residual resistivity values reported, assumed to be measured at 4.2 K; data extracted from table.
17	391	Zwingmann, G.	1963	V, B	293	94.02-99.50	Average purity of component metals 99.9; final wire specimens 0.8 mm in diam; components melted in DEGUSSIT AL23 or ZR23 crucible partly under Ar and partly under vacuum of 10^{-3} Torr, formed into round ingots of 9 mm diam, homogenized partly under Ar and partly under a vacuum of 10^{-4} Torr at 1173 to 1473 K, homogenizing times were 8 h for alloys with more than 5 a/o solute and 4-6 h for lesser concentrations, formed into wires with intermittent annealing, finally annealed in manner similar to the homogenization; change in resistivity upon alloying relative to pure Pd reported in figure, resistivity of pure Pd annealed at 923 K in high vacuum was $10.85 \times 10^{-8}\ \Omega m$ at 293 K; increase in resistivity per atomic percent Ag in Pd was $1.17 \times 10^{-8}\ \Omega m$.
18	392	Simon, P.R.F.	1965		4.2	1.2-95.0	Spectrographically pure components; wire specimens 1 mm in diam and 100 mm long supplied by Johnson, Matthey, and Co. Ltd.; annealed under vacuum for 36 h at 953 K; data read from figure.

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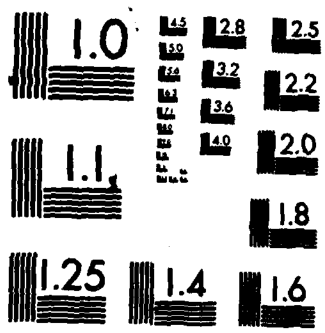
1.0
4.5
5.0
5.6
6.3
7.1
8.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

TABLE 69. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Pd)	Composition (weight percent), Specifications, and Remarks
19	393	Guénault, A.M.	1974		4.2	1-95.8	Wire specimens from three sources: most were prepared by M.J. Walker, University of Leeds by melting, turning, and remelting the pure metal sponges in Ar arc furnace and then forming 0.5 mm diam wires by rolling and drawing through tungsten and diamond dies and finally annealing in vacuum; others were selected samples of Kemp, Klemens, Sreedhar, and White (Ag + Pd data sets 29-44 and Pd + Ag data sets 13-18); one sample was from earlier work by Guénault; these sources are denoted by [L], [K], and [G], respectively; compositions of all but the sample from [G] were determined by chemical analysis and trace impurities by mass spectrographic analysis by Fulmer Research Institute; the sources and wt.% impurities of the samples in the order in which they appear in the experimental data table are: [G], not determined; [L], 0.0020 Fe, 0.0005 Cu; [L], 0.0015 Cu, 0.0005 Fe; [L], 0.0020 Fe, 0.0010 Cu; [K], 0.0150 Cd, 0.0100 Cu, 0.0030 Fe, 0.0010 Pt, 0.0010 Zn; [K], 0.0150 Cd, 0.0100 Cu, 0.0100 Fe, 0.0010 Pt, 0.0010 Zn; [L], 0.0015 Cu, 0.0010 Fe; [L], 0.0030 Fe, 0.0015 Cu; [K], 0.1500 Fe, 0.0300 Cu, 0.0040 Pb, 0.0040 Zn, 0.0015 Ni; [L], 0.0005 Cu, 0.0003 Fe; [L], 0.0050 Cu, 0.0030 Fe; [K], 0.0050 Cu, 0.0030 Fe, 0.0030 Ni, 0.0030 Pt, 0.0010 Au, 0.0010 Zn; [L], 0.0050 Cu, 0.0030 Fe; [L], 0.0050 Cu, 0.0050 Fe, 0.0010 Zn; [L], 0.0005 Cu, 0.0003 Fe; analysis of resistivity and thermopower of the 49.8 a/o Pd sample indicated a more likely composition of 51 a/o Pd, the 42.5 a/o Pd sample had an irregular large-grained appearance; data extracted from table.
20	394	Carson, A.W., Lewis, F.A., and Schurter, W.H.	1966		298	45.20-89.92	Wire specimens 0.122 and 0.274 mm in diam prepared by arc-melting under argon; fcc lattice parameters of the 50.74, 60.93, 70.78, 74.16, 80.91, and 89.92 a/o Pd alloys were 3.981, 3.962, 3.940, 3.937, 3.916, and 3.903 Å, respectively; data extracted from table.
21	395	Szafranski, A.W.	1973	A	4.2	60.9-95.0	Foil specimens 0.01 x 1 x 10 mm were cold-rolled and not annealed; data read from figure.
22	308	Barber, A.J. and Caplin, A.D.	1975	A	0	0.0078-1.07	Nominal compositions; wire specimens 0.25 mm to 0.89 mm in diam prepared by melting high purity Ag and Pd in quartz ampoules, homogenizing, rolling, and drawing; annealed at 873 K for 6-10 h in sealed capsule with up to 10 Torr oxygen or in a continuous flow of oxygen at 10^{-1} Torr in order to precipitate Fe; measured in helium environment; less than 1% uncertainty in geometrical factor, uncertainty in measurement temperatures less than ± 100 mK; lowest measurement temperature was 1.5 K, residual resistivities obtained by extrapolation to 0 K were extracted from table.
23	368	Savitskii, E.M. and Pravoverov, N.L.	1961	A	298	5-95	20 g charges of 99.98 pure Pd and 99.99 pure Ag fused under molten borax in alumina crucibles in a high-frequency furnace, forged while hot, rolled on manual rolling mill without intermediate annealing, and finally annealed in evacuated quartz tubes at 1273 K for 124 h and at 1073 K for 200 h; loss in weight was not observed after fusion; microstructural analysis showed polyhedral crystals of solid solutions with well-defined grain boundaries for all compositions; authors concluded existence of ordered compounds at 50 and 60 a/o Pd upon annealing at 1273 to 1073 K; data read from figure.
24	396	Couper, A. and Metcalfe, A.	1966		293	0.6-99.2	Specific resistivity of filament specimens; measurement temperature not stated explicitly, assumed to be 293 K; data read from figure.

TABLE 69. MEASUREMENT INFORMATION ON THE ELECTRICAL RESISTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM (Composition Dependence) (continued)

Data Set No.	Ref. No.	Author(s)	Year	Method Used	Temp., K	Composition Range (At.% of Pd)	Composition (weight percent), Specifications, and Remarks
25	384	Arajs, S., Rao, K.V., Yao, Y.D., and Teoh, W.	1977	A	~300	50.0-69.7	99.99 pure Pd sponge from Engelhard Industries Inc. and 99.999 pure Ag from American Smelting and Refining Co. arc-melted together to form ingot weighing about 10 g; ingots sealed in evacuated silica tubes, homogenized at about 1300 K for 60 h, drawn to 1 mm^2 cross-section, cleaned, re-sealed in evacuated silica capsules, annealed at 1200 K for 1 h, and rapidly cooled in air without breaking the capsules; data read from figure; pre-print kindly supplied by K.V. Rao in private communication.
26	397	Rao, K.V., Rapp, Ö, Johanneson, C., and Aström, H.U.	1977		300	49.9-97.2	Data not yet published at time of preparation of this report; authors will publish in "Electrical Resistivity of Fe Dissolved in Pd-Ag Matrix Alloys," Physica B, International Conference on Magnetism, 1976 Proceedings; the data were presented concomitantly in the pre-print of the article by Arajs et al. (see data set 25 of this table) which was supplied by K.V. Rao in private communication; no measurement information available; data read from figure.
27	398	Krüger, F. and Gehm, G.	1933		293	0-100	Homogenized in high vacuum for several hours between 1023 and 1073 K, quenched in water at room temperature; lattice constants of the 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 a/o Pd alloys were 4.078, 4.052, 4.030, 4.011, 3.990, 3.970, 3.950, 3.933, 3.916, 3.899, and 3.884 Å respectively; measurement temperature was room temperature, assumed to be 293 K; data extracted from table.

TABLE 70. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF SILVER–PALLADIUM ALLOY SYSTEM (Composition Dependence)

[Composition, C, a/o Ag; Electrical Resistivity, ρ, $10^{-8}\ \Omega m$]

C	ρ
DATA SET 1 (T = 293.2 K)	
1	2.0
4	3.2
10	5.5
20	10.0
30	15.4
40	21.3
50	29.4
60	41.7
70	37.0
80	28.6
85	22.7
96	13.0
98	11.1
100	9.5
DATA SET 2 (T = 298.2 K)	
0	1.66
10	5.71
20	9.44
30	14.1
40	20.2
45	25.2
50	30.6
55	37.2
60	42.0
65	42.9
70	41.2
80	33.0
90	22.8
100	11.1
DATA SET 3 (T = 293.2 K)	
0	1.6*
11.1	5.6
20.1	10.0
30.5	14.8
40.8	20.8
45.9	24.2
50.6	30.9
55.8	39.2
61.0	42.9
DATA SET 3 (cont.) (T = 293.2 K)	
65.8	43.0
70.7	40.1
80.5	32.3
89.4	22.4
100	10.6
DATA SET 4 (T = 4.2 K)	
11.1	4.0
20.1	8.4
30.5	13.1
40.8	18.6
45.9	21.9
50.6	28.2
55.8	36.9
61.0	40.2
65.8	39.1
70.7	34.5
80.5	24.1
89.4	12.2
DATA SET 5 (T = 298 K)	
9.53	6.6
21.43	11.4
32.81	17.3
41.80	22.8
53.53	36.6
DATA SET 6 (T = 77.4 K)	
5	2.46
10	4.43
20	8.61
25	11.48
30	13.25
35	15.60
40	19.22
45	22.45
50	30.20
100	2.70
DATA SET 7 (T = 273.2 K)	
0	1.57
10.08	6.06
20.16	10.44
30.22	15.41
40.26	21.74
50.27	32.79
60.27	42.02
70.23	38.76
80.17	30.67
90.10	20.62
100	10.56
DATA SET 8 (T = 291.2 K)	
0	1.6*
10.3	6.0
21.6	10.8
29.3	15.1
40.0	21.4
50.5	31.9
58.5	41.3
69.1	42.2
70.3	40.8
85.1	28.0
94.4	17.8
100	10.6*
DATA SET 9 (T = 298.2 K)	
0	2.01
10.1	6.20
20.2	10.56*
30.3	15.55
40.3	21.93
50.3	33.00
60.3	42.02*
70.3	39.06
80.2	31.15
90.1	21.23
100	11.51
DATA SET 10 (T = 4.2 K)	
2.11	0.925
5.13	2.21
10.02	4.39*
20.30	8.45
29.91	12.86
40.33	19.16
50.34	29.86
70.29	35.60
95.06	6.61
DATA SET 11 (T = 293.2 K)	
2.11	2.54
5.13	3.81
10.02	6.035*
20.30	10.00
29.91	14.55
40.33	21.40
50.34	33.00*
70.29	40.90*
95.06	17.20
DATA SET 12 (T = 4.2 K)	
2.11	0.89*
5.13	2.20*
10.02	4.15
20.30	8.25
29.91	12.78*
40.33	18.10
50.34	27.70
70.29	35.60*
95.06	5.81
DATA SET 13 (T = 293.2 K)	
2.11	2.52*
5.13	3.91*
10.02	6.00*
20.30	10.10*
29.91	14.66*
40.33	21.10
DATA SET 13 (cont.) (T = 293.2 K)	
50.34	30.5
70.29	40.9*
95.06	16.8
DATA SET 14 (T = 293 K)	
0	2.6
09.4	6.9
19.5	11.1
29.6	15.3
40.5	21.5
50.8	31.8
60.7	42.0
70.6	41.9
80.3	35.1
90.6	25.5
100	12.8
DATA SET 15 (T = 4.2 K)	
90.05	10.6
92	7.73
94.44	5.66
96.3	3.48
98	1.95
99.01	0.95
99.52	0.68
99.75	0.50
99.9	0.23*
99.95	0.13
DATA SET 16 (T = 4.2 K)	
90.27	12.18
95.22	5.92
DATA SET 17 (T = 293 K)	
94.02	17.83
96.01	15.50
97.00	14.31
DATA SET 17 (cont.) (T = 293 K)	
98.00	13.14
99.00	11.98
99.50	11.35
DATA SET 18 (T = 4.2 K)	
1.2	0.5
9.9	4.7
20.0	8.6*
40.0	18.3
43.0	19.3
45.3	20.4
50.0	27.7
52.1	30.0
55.0	34.8
56.9	36.2
60.0	39.6
70.0	36.9
80.0	26.9
90.0	15.9
95.0	13.3
DATA SET 19 (T = 4.2 K)	
1	0.43
2.4	1.09
9.8	4.13
21.9	8.2
31.4	12.4
40.2	18.0
42.5	14.9
49.8	29.5
50.1	27.4
59.4	38.9
70.1	33.5
70.3	34.4
81.4	22.6
91.7	10.3
95.8	6.5
DATA SET 20 (T = 296 K)	
45.20	27.42

* Not shown in figure.

TABLE 70. EXPERIMENTAL DATA ON THE ELECTRICAL RESISTIVITY OF SILVER-PALLADIUM ALLOY SYSTEM (Composition Dependence) (continued)

DATA SET 20 (cont.)
(T = 298 K)

C	ρ
50.74	32.49
55.25	40.60
60.93	44.14
65.24	46.96
70.78	43.81
74.16	33.96
80.91	30.11
89.93	22.56

DATA SET 21
(T = 4.2 K)

C	ρ
60.9	39.6
76.7	28.0
85.6	18.0
90.1	12.2
95.0	5.7

DATA SET 22
(T = 0 K)

C	ρ
0.0078	0.00607
0.091	0.0415*
0.091	0.0422*
0.66	0.2900
0.90	0.4000*
1.07	0.4720*

DATA SET 23
(T = 298 K)

C	ρ
5	4.38
10	5.93*
15	8.00
20	9.85
25	12.40
30	14.05*
35	15.10
40	18.03
45	23.03
50	24.95
55	33.20
57.5	30.35
60	27.93
61	32.10
62.5	37.08
65	37.43

DATA SET 23 (cont.)
(T = 298 K)

C	ρ
70	36.28
75	33.33
80	29.53
85	26.00
90	21.53
95	16.53

DATA SET 24
(T = 293 K)

C	ρ
0.6	2.00*
10.1	6.14*
20.3	10.24
40.5	21.36*
60.8	39.84
65.4	40.87
70.5	39.54
80.1	31.77
90.1	17.46
99.2	10.60

DATA SET 25
(T = 300 K)

C	ρ
50.0	31.88
55.0	41.28
59.5	44.86
6[illegible] 9	43.70
[illegible] 7	39.73

DATA SET 26
(T = 300 K)

C	ρ
49.9	35.95
66.7	44.28
74.8	39.54
89.7	27.62
97.2	18.12

DATA SET 27
(T = 293 K)

C	ρ
0.0	1.7*
10.08	6.6
20.16	11.0
30.22	16.7
40.26	24.7

DATA SET 27 (cont.)
(T = 293 K)

C	ρ
50.27	33.1*
60.27	45.5
70.23	43.5
80.17	37.0
90.10	27.3
100.0	11.6*

* Not shown in figure.

4. ACKNOWLEDGMENTS

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5. APPENDICES

5.1. Analysis of the Electrical Resistivity of Gold-Silver Alloy System

In deriving recommended values of $\rho(c,T)$ for binary alloys from experimental results for various temperatures T and mole fractions c of one component, one faces the considerable problem of correlating the results in such a way as to smooth out, so far as is possible, the effects of the various errors that may influence the individual measurements. When the full range of T and c is to be dealt with, this cannot be done by getting a "best fit" (in some sense) of a smooth approximating function of T and c to the reported values of ρ, since it is not clear what manifold of approximating functions should be considered. Given, as in the case of the Au-Ag alloy system, values of ρ measured for a reasonably large number of values of T on samples with a reasonable number of values of c, cross-plotting is effective.

The precise tactics to be employed in cross-plotting may depend on the data available in a particular case. One may, for instance, begin with plots of measured ρ against T for each value of c for which sufficient data is available. Through each set of points one can draw a smooth curve, or T-plot, to represent $\rho(c,T)$ for that value of c. The choice of such curves is always subject to arbitrariness, but an immediate check is available if one can assume that $\rho(c,T)$ is a smoothly varying function of c: one can plot values of ρ read from these curves against c, for various test temperatures T_t. If each such set of points lies on a smooth curve, this c-plot can be taken to represent the variation of $\rho(c,T)$ with c for the given T_t. If not, the original T-plots should be re-examined and revised until an acceptably smooth c-plot can be passed through the points corresponding to each T_t. When this has been accomplished, one can derive from the revised T-plots a set of c-plots for any desired set of temperatures T_i, and from these, by cross-plotting again, a set of T-plots for any desired set of c_j. Smoothing can be introduced at each step in repeated cross-plotting, but care must be taken that the end result of multiple smoothing remains consistent with the original data.

If one lacks assurance that $\rho(c,T)$ is a smooth function of both c and T, the value of cross-plotting is correspondingly reduced. It may also be

noted that scattered values of $\rho(c,T)$ are of little value during the process of cross-plotting, but may be useful in testing the final results.

Instead of cross-plotting $\rho(c,T)$, it is often better to work with

$$\rho_i(c,T) = \rho(c,T) - \rho_0(c), \tag{A1}$$

where $\rho_0(c)$ is the residual resistivity of the alloy (or, usually, with adequate accuracy, its measured resistivity at 4K). This temperature-dependent part of $\rho(c,T)$ changes more slowly with c than does the total ρ, and its isotherms may form a family more convenient for cross-plotting. In the case of the Au-Ag system it has proved very useful to go further in this direction, to work with the quantity

$$\Delta(c,T) = \rho_i(c,T) - \bar{\rho}_i(c,T), \tag{A2}$$

where $\bar{\rho}_i$ is the atomic-fraction-weighted average of the intrinsic resistivities of the pure metals:

$$\bar{\rho}_i(c,T) = c\rho_i^{(Ag)}(T) + (1-c)\ \rho_i^{(Au)}(T) \tag{A3}$$

with $c \equiv c_{Ag}$. The motivation for this choice will be clear from figure A-1, where results of measurements of Giauque and Stout [297] (Au + Ag data sets 24-26, Ag + Au data sets 21 and 22, and Au-Ag data sets 16-20) on a series of alloys ($c = 0.1$ to $c = 0.9$) are presented by plotting $\rho_i(c,T)/T$ against c, for seven temperatures ranging from 14 K to 298 K. Corresponding values for small c, derived from the results of Stewart and Huebener [301] (Au + Ag data sets 59 and 60 and Au-Ag data set 14), and for small (1-c), derived from the results of Dugdale and Basinski [29] (Au-Ag data set 15) are also given for these temperatures. Comparison of the plotted values of ρ_i/T for each temperature with the straight line between the end points (the pure metals), which represents $\bar{\rho}_i(c,T)/T$, shows that Δ/T is small and varies only slowly with c for $0.2 \le c \le 0.8$. By definition, it vanishes as c approaches 0 or 1 at any T, and (barring highly unlikely behavior of ρ at low temperatures) as T goes to 0 for any c. Figure A-1 also shows that Δ/T (like ρ_i/T, $\rho_i^{(Ag)}/T$, and $\rho_i^{(Au)}/T$) changes only slowly with T at high temperatures, and even down to quite low temperatures.

The quantity Δ, which is at most a few percent of ρ, is the small correction to the good approximation

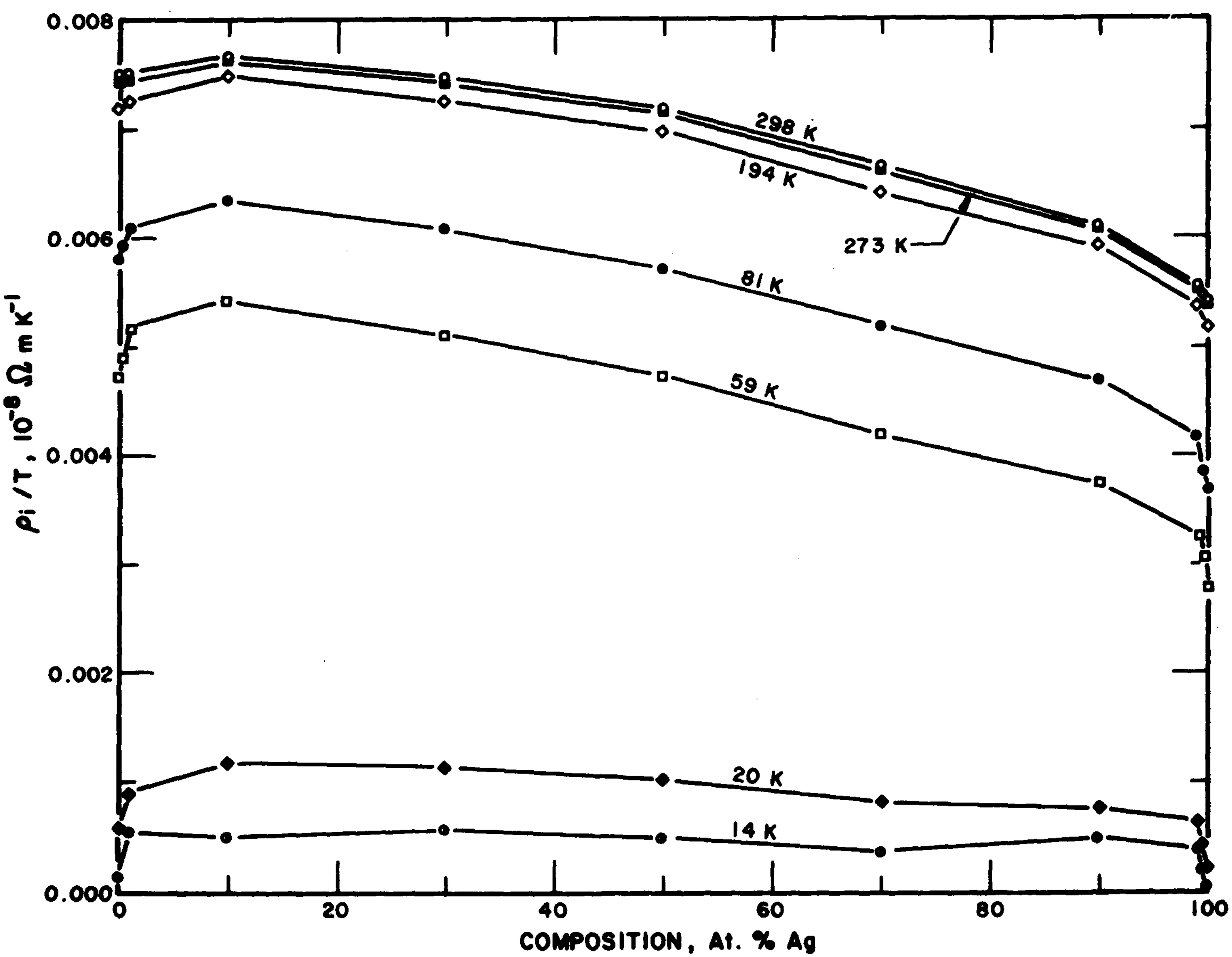

Figure A-1. $\rho_i(c,T)/T$ as a Function of T. Pure Metal Values Recommended by CINDAS, Values for c = 0.25 and 1 At.% from data of Stewart and Huebener [301], for c = 10 to 90 At.% from data of Giauque and Stout [297], and for c = 99 and 99.5 At.% from data of Dugdale and Basinski [29].

$$\rho(c,T) \underset{=}{\sim} \rho_0(c) + \bar{\rho}_1(c,T). \tag{A4}$$

Irregularities and discrepancies in values of $\rho(c,T)$ become very conspicuous in plots of Δ or Δ/T, and this increases the confidence with which one can reject some data as aberrant or unreliable. Cross-plotting of Δ is convenient up to 300 K, and cross-plotting of Δ/T down to 100 K; the range of overlap in T makes it useful to employ both types of plot in relating low-T data to high-T data.

As examples, figures A-2 and A-3 show values of Δ/T derived from five sets of measurements, for $c_{Ag} = 0.5$ and 0.9, respectively. The indicated curves were derived by cross-plotting values of Δ, starting from data on samples with c = 0.05, 0.1, 0.3, 0.5, 0.7, 0.75, 0.9, 0.95, and 0.97 for which the authors had measured $\rho(c,4K)$ as well as ρ at higher temperatures. (As will be discussed later, availability of $\rho(c,4K)$ eliminates some sources of error in the determination of Δ.) The value of $\rho(c,4K)$ was available for all data illustrated in figures A-2 and A-3 except that of Iyer and Asimow [302] (Au + Ag data sets 2-5, Ag + Au data sets 11-13, and Au-Ag data set 46), for which $\rho_0(c)$ had to be deduced from a ρ_0 versus c curve and the stated c. The correction for thermal expansion of the samples, made by Iyer and Asimow, has been removed in calculating Δ/T is order to maintain uniformity in the neglect of this correction. Data of Grüneisen and Reddemann [128] (Au + Ag data sets 27 and 28 and Ag + Au data sets 23 and 24) is not represented in figure A-2, since two of the three values of Δ/T derived from their measurements lie outside the range of the figure.

The results of cross-plotting Δ to lower temperatures is illustrated, for the Ag-rich alloys, in figure A-4. The crosses represent values read from cross-plots of Δ/T. Also shown are values of Δ for c = 0.99 and 0.995, as deduced from the results of Dugdale and Basinski [29] (Au-Ag data set 15), who were primarily concerned with deviations from Matthiesson's Rule; their correction for thermal expansion was removed, but not their correction for change of volume on alloying, which they describe as small. These data are consistent with the idea (not necessarily correct) that Δ increases monotonically with c at all T, and this idea has been used as a guide in extrapolating to the very small corrections at the lowest T. For small c a similar relation was found between values of Δ derived from cross-

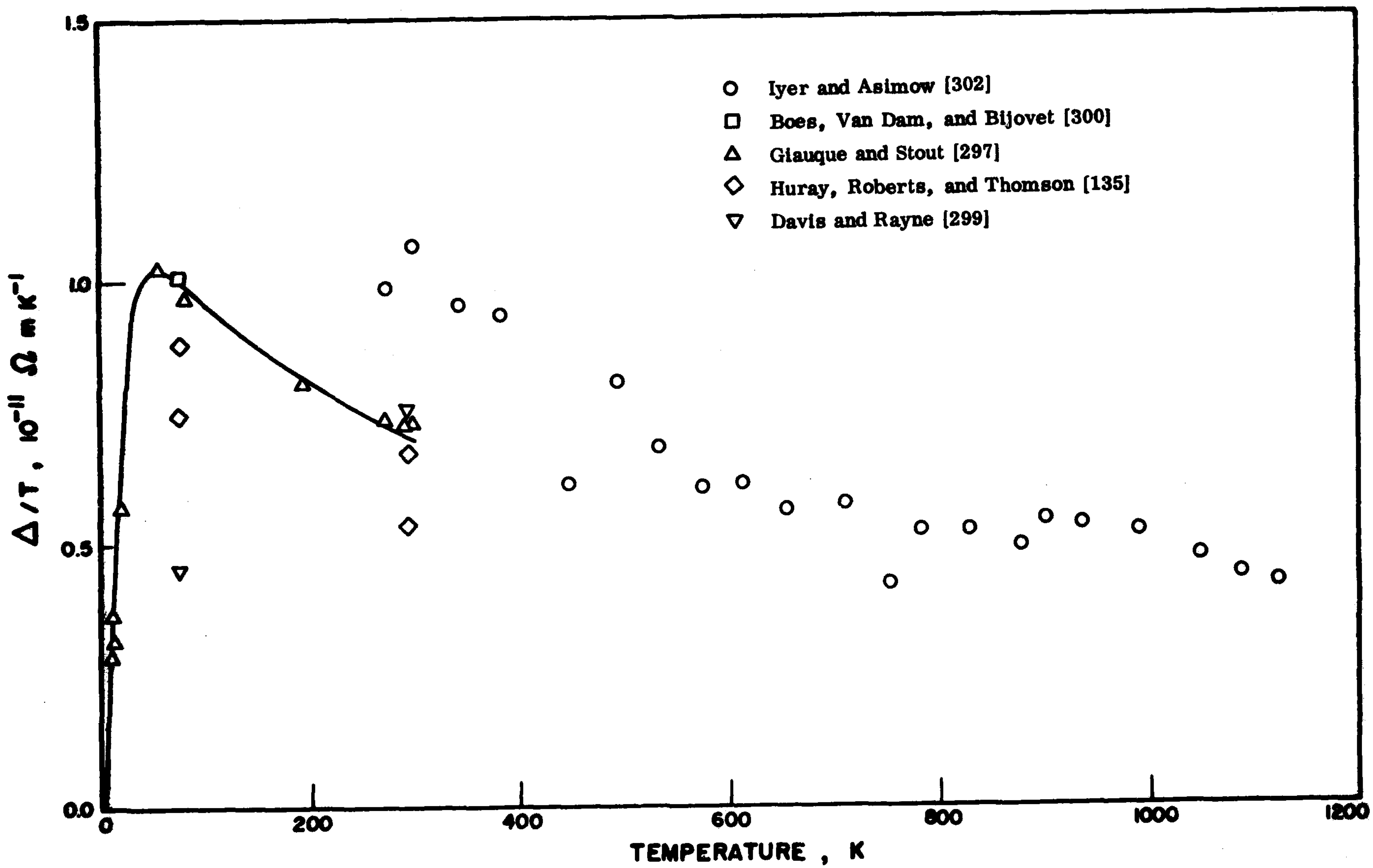

Figure A-2. Δ/T as a Function of T for c_{Ag} = 50 At.%. Data Points and Estimated Curve t 300 K.

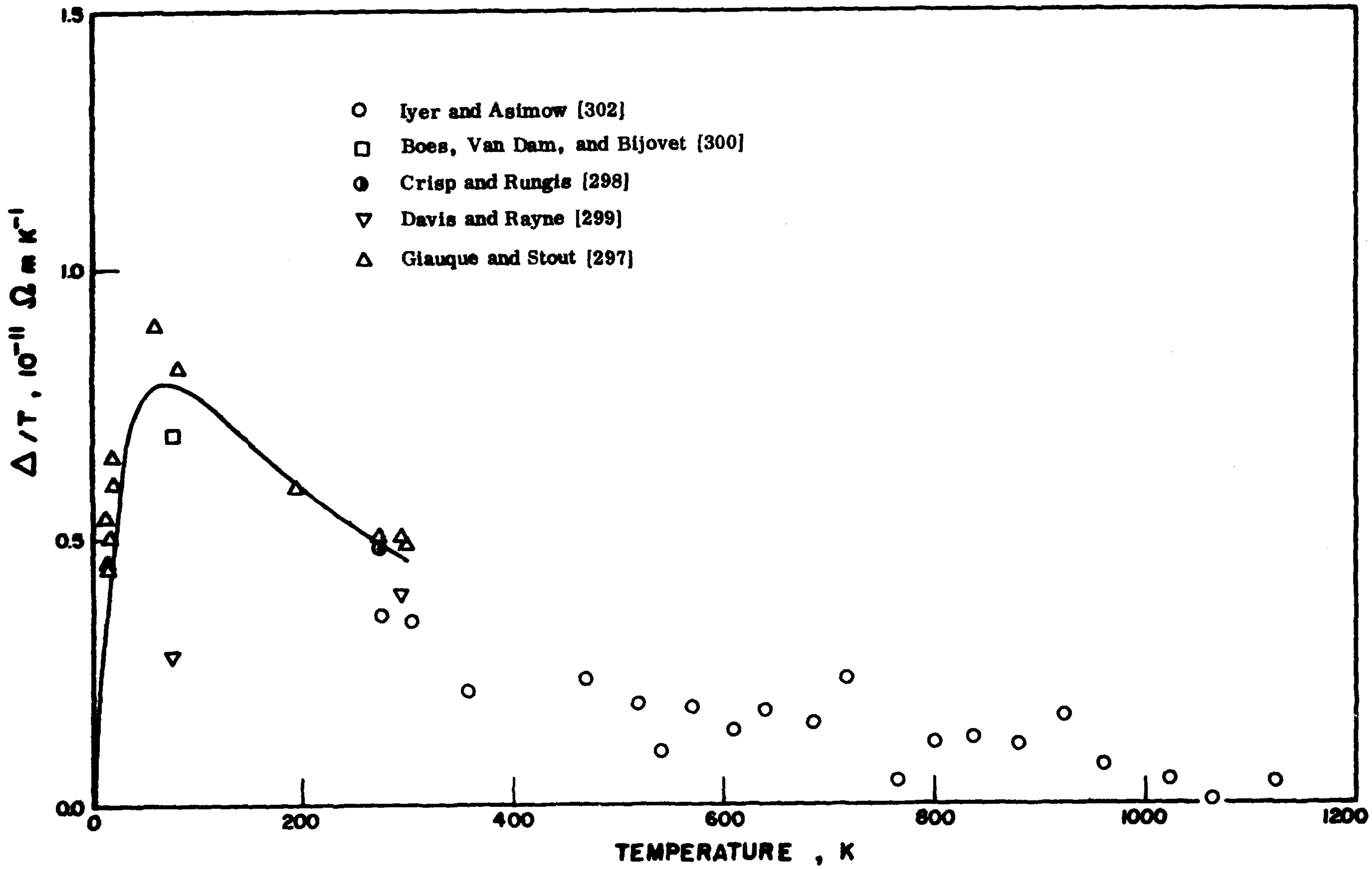

Figure A-3. Δ/T as a Function of T, for $c_{Ag} = 90$ At.%. Data Points and Estimated Curve to 300 K.

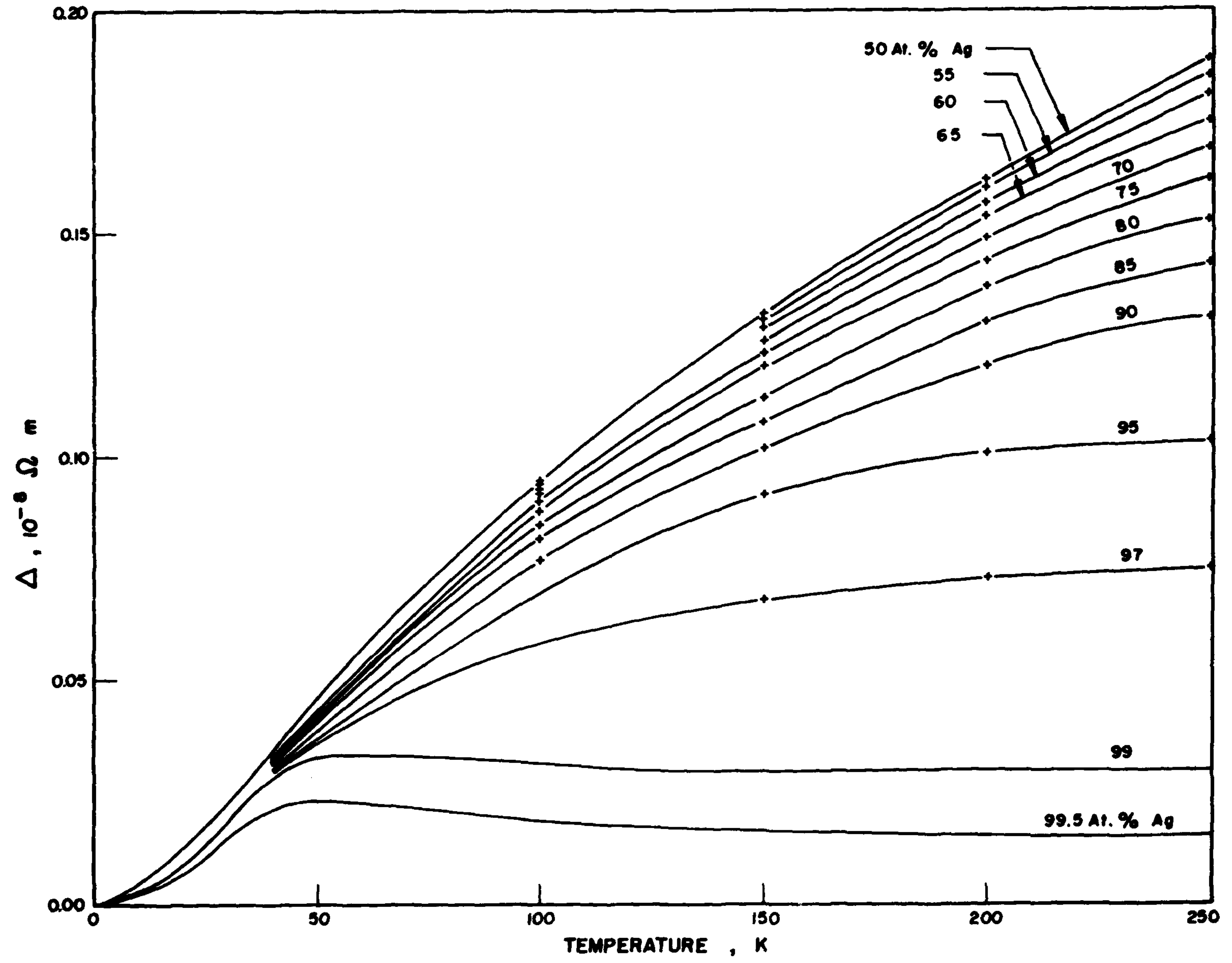

Figure A-4. Δ as a *Function of* T, *for* Silver-Rich Alloys, as Derived from Cross Plots of Δ/T. Values for c_{Ag}=99 and 99.5 At.% are Derived from Data of Dugdale and Basinski [29], as Described in Text.

plots of Δ/T for $c \geq 0.05$ and values derived from the results of Stewart and Huebener [301] (Au + Ag data sets 59 and 60 and Au-Ag data set 14) for $c \leq 0.01$. For interpolation to low values of c it is convenient to use cross-plots of $\rho(c,T)/c$ against c.

For the solid above room temperature the only data useful in cross-plotting are those of Iyer and Asimow [302], for c = 0.05, 0.1, 0.3, 0.5, 0.7, 0.9, and 0.95. As is illustrated in figures A-2 and A-3, values of Δ derived from their data do not always join smoothly onto values derived from other data at room temperatures and below. This appears to be due in part to errors that (as concerns data obtained for a single sample at many temperatures) may be regarded as systematic, and that are absent from the low-T values of Δ. The low-T values were computed as

$$\Delta(c,T) = \rho(c,T) - \rho(c,4K) - \bar{\rho}_i(c,T) \tag{A5}$$

with the first two terms on the right measured on the same sample. An error δc in control of the c for the sample will change the sum of these two terms by just $(\partial\rho_i/\partial c)\ \delta c$. Errors in determination of the dimensions of the sample, said by Iyer and Asimow to be the major source of error in their results, will change the sum of these two terms by a fixed fraction of ρ_i, which we write as $\rho_i\ \delta\ell$, with $\delta\ell$ a measure of the overall effect of dimensional errors. Together, these errors change Δ by

$$\delta\Delta = \frac{\partial\rho_i}{\partial c}\ \delta c + \rho_i\ \delta\ell. \tag{A6}$$

Both terms on the right tend to be small because ρ_i is smaller than ρ and is, indeed, very small at low temperatures. In processing the data of Iyer and Asimow, on the other hand, it was necessary to use eq (A2) instead of eq (A5). The errors δc and $\delta\ell$ then effect only the first term on the right of eq (A2), and there is no partially cancelling contribution from the second term; in addition, there is an independent error, $-\delta\rho_0(c)$, arising from any error $\delta\rho_0(c)$ in the value assigned to ρ_0 at the nominal c. Together, these sources of error will change Δ by

$$\delta\Delta = \{\frac{\partial\rho_0}{\partial c} + \frac{\partial\rho_i}{\partial c}\}\ \delta c + \{\rho_0 + \rho_i\}\ \delta\ell - \delta\rho_0(c). \tag{A7}$$

The difference between eqs (A6) and (A7) represents a systematic difference between the Δ's derived from the low-T data and the data of Iyer and Asimow, respectively.

Since the sources of error should be less important for the low-T results, it seems reasonable to use those results as reference points in reducing the effects of the errors δc, $\delta \ell$ and $\delta \rho_0$ on the values of Δ derived from the data of Iyer and Asimow. This can be done by adjusting the available parameters to make the corrected values $\Delta - \delta\Delta$ for the high-T data continue smoothly, in the region 300-400 K, the trend established by cross-plotting the low-T data. The process involves no great arbitrariness because $\delta\Delta$ for any sample is nearly a linear combination of two known functions of T: a constant, and $\bar{\rho}_i(c,T)$. For the Ag-Au alloys one has, with all the accuracy needed in computing this small correction,

$$\rho_i \cong \bar{\rho}_i, \tag{A8}$$

$$\frac{\partial \rho_i}{\partial c} \cong \frac{\partial \bar{\rho}_i}{\partial c} = \rho_i^{(Ag)}(T) - \rho_i^{(Au)}(T). \tag{A9}$$

Further, though $\bar{\rho}_i$ and $(\partial\bar{\rho}_i/\partial c)$ involve the metal resistivities in quite different ways, they change with T in nearly the same way because the T-dependences of the pure-metal resistivities are so similar. This is illustrated in table A-1.

Table A-1. Values of $\rho(T)/\rho(300\ K)$

T,K	$\dfrac{\rho_i^{(Ag)}(T) - \rho_i^{(Au)}(T)}{\rho_i^{(Ag)}(300K) - \rho_i^{(Ag)}(300K)}$	$\bar{\rho}_i(T)/\bar{\rho}_i(300\ K)$				
		Mole Fraction of Silver				
		0.1	0.3	0.5	0.7	0.9
300	1	1	1	1	1	1
600	2.13	2.15	2.15	2.15	2.15	2.15
900	3.54	3.45	3.44	3.44	3.43	3.42
1200	5.43	5.01	4.98	4.95	4.92	4.89

Since $\rho_i^{(Ag)} - \rho_i^{(Au)}$ is about a third as large as ρ_i, and only small corrections are involved, one can reasonably take the T-dependence of the second of the five terms on the right in eq (A7) to be the same as that of the fourth. Replacing $(\partial\rho_i/\partial c)$ by $\kappa\rho_i(c)$, we have

$$\delta\Delta \cong \{\frac{\partial\rho_0}{\partial c}\ \delta c + \rho_0(c)\ \delta\ell - \delta\rho_0(c)\} + \overline{\rho}_i(T,c)\{\kappa\delta_c + \delta\ell\}, \qquad \text{(A10)}$$

where the quantities in braces are independent of T. Adjustment of these two constants to achieve a smooth fit of high-T to low-T data does not, of course, make it possible to estimate the three errors δc, $\delta\ell$, $\delta\rho_0$ for a particular high-T sample.

In treating the Au-Ag alloys, the fit between high-T and low-T Δ's was actually made on plots of Δ/T, such as figures A-2 and A-3. Analysis of the low-T data yielded plots that were nearly linear in T from 100 to 300 K, and appeared to fix Δ at 300 K with an error not exceeding 0.03×10^{-8} Ωm for any c. For each of the seven compositions mentioned above, smooth curves were then passed through the high-T data points, with the intention of smoothing out the effect of random errors. This was done as carefully as possible by eye and French curve, without consideration of the relation of curves for different c, except in one case: c = 0.3. For this composition the three points derived from the data of Iyer and Asimow for 293 K ≤ T ≤ 350 K were far out of line with the other points, and a curve passed through them could not be made to fit in with other curves, either before or after adding the correction $-\delta\Delta$. These three points were therefore ignored, and the smoothed curve was passed through the remaining points with knowledge of, but no detailed attention to, the trend of the corresponding curves for other compositions. Each smoothed high-T curve was then matched to the corresponding smoothed low-T curve by addition of a correction $-\delta\Delta$ that brought it to the same value at 300 K and at 400 K. The T-plots formed by this union of the high-T and low-T parts were then tested by cross-plotting. The results were acceptable, and further study of the possibilities led to no change in the initial T-plots. From these T-plots a complete set of c-plots was derived, and from these in turn a complete set of T-plots.

Figure A-5 illustrates the effect of the correction $-\delta\Delta$ on the high-T data shown in figure A-3; it also shows the final T-plot for c = 0.9. Figure A-6 shows the final c-plots of Δ/T, which are particularly useful for interpolation or extrapolation at high T.

It is now necessary to consider the uncertainty in the values of ρ(c,T) derived by adding the estimated Δ(c,T) to the interpolative approxi-

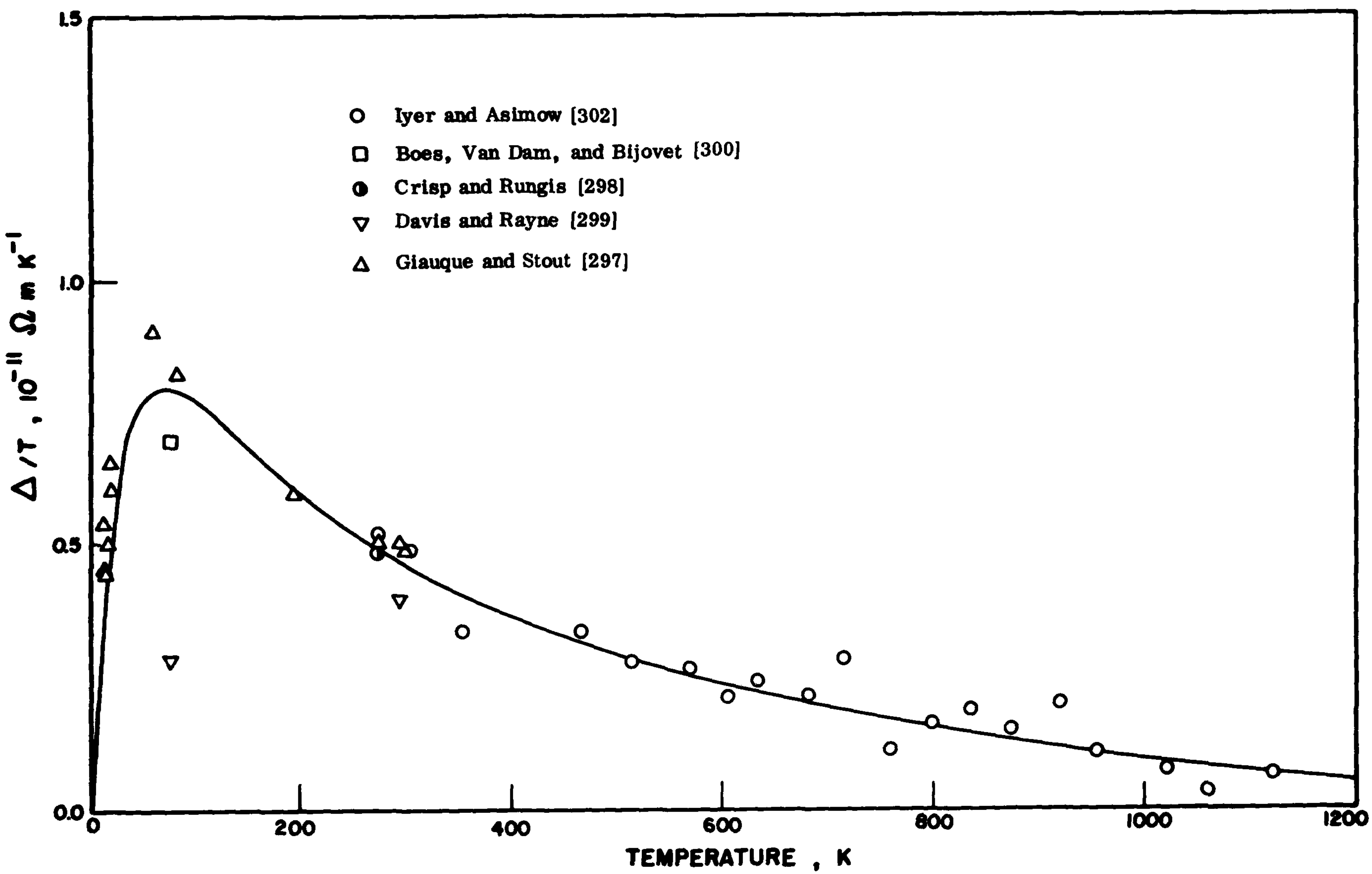

Figure A-5. Δ/T as a Function of T, for c_{Ag} = 90 At.%. Data Points of Iyer and Asimow are Adjusted as Described in Text, and Estimated Curve is Extended to 1200 K.

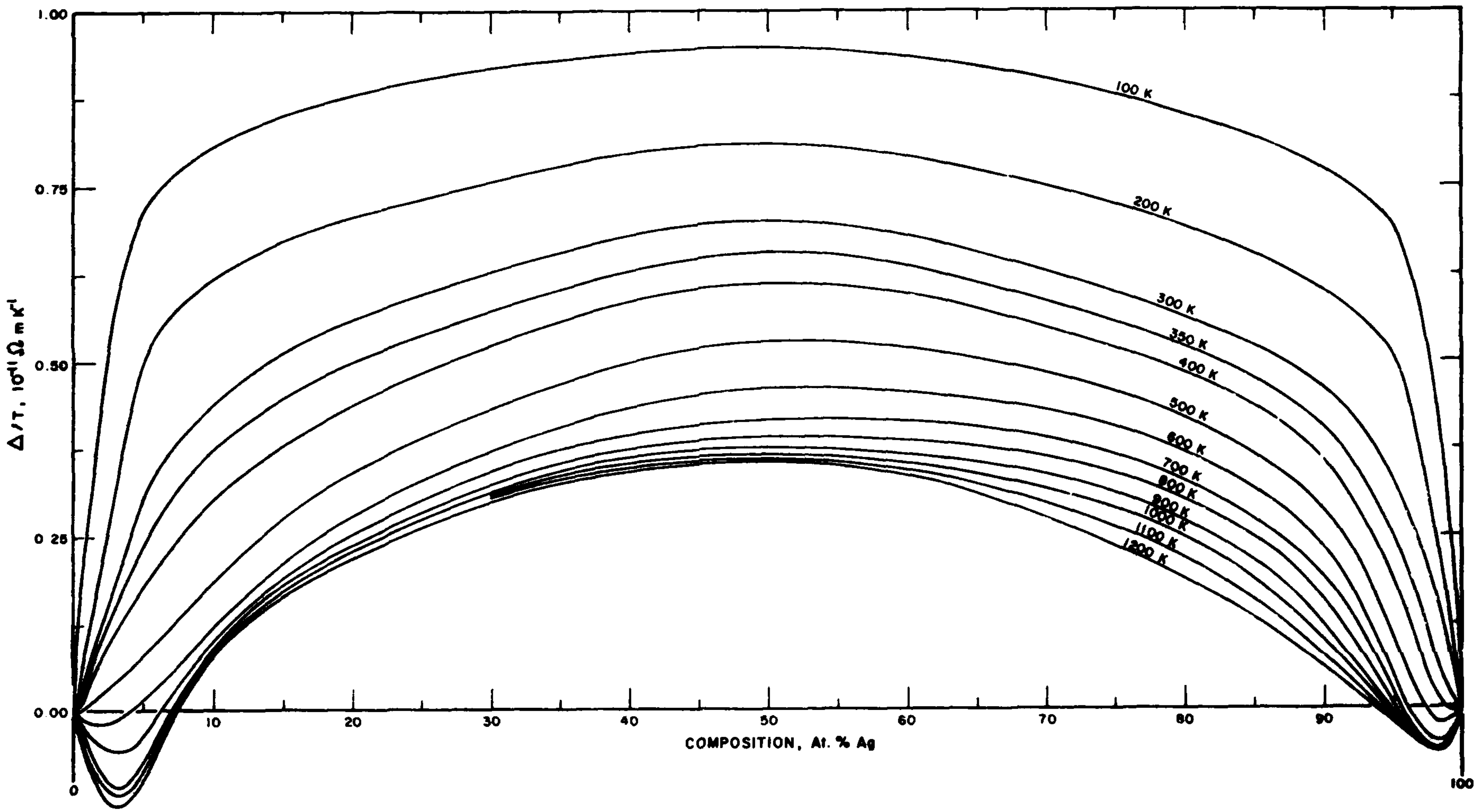

Figure A-6. Final Plot of Δ/T as a Function of Composition for Fixed Temperatures.

mation given by eq (A4). This uncertainty arises, not just from the uncertainties involved in constructing plots of Δ, but from the fact that one must use throughout, not the exact values of $\rho_0(c)$ for alloys and of $\rho_i(T)$ for the pure metals, but the best available approximations.

We consider first the uncertainties in the process of correcting the high-T data, of which a detailed study was made in the case of c = 0.5. It was found that alternative choices of the smoothed curve through the uncorrected data points, together with different ways in which the smoothed high-T curves could be fitted to the low-T curve without an evident discontinuity in the slope, could shift the inferred value of Δ at 1000 K only by $\pm 0.1\ 10^{-8}\ \Omega m$. Since independent adjustments of this magnitude in the T-plots for different c would make trouble with the c-plots, $\pm\ 0.1\ 10^{-8}\ \Omega m$ seems to be a reasonable, and even high, estimate of the uncertainty in Δ at 1000 K due to uncertainties in the fitting process. To this error of fitting one must add the uncertainty of the low-temperature Δ at 300 K. Estimates of the possible constructional errors in Δ, intended to be safe maxima, are shown in table A-2. These apply to the construction of all the original T-plots, for c ranging from 0.05 to 0.95.

Table A-2. Estimated Maximum Error in Constructing T-Plots

T,K	Uncertainty in Δ, $10^{-8}\ \Omega m$
100	0.015
200	0.02
400	0.04
600	0.06
800	0.085
1000	0.11
1200	0.14

In this method of analysis, the primary reason for subtracting $\rho_0(c)$ and $\bar{\rho}_i(c,T)$ from the observed $\rho(c,T)$ is to get a smaller or more slowly changing quantity ($\Delta(c,T)$, or Δ/T, or Δ/c) to study. Then inevitable errors in the assumed $\rho_0(c)$, $\rho_i^{(Ag)}(T)$, and $\rho_i^{(Au)}(T)$, if smoothly changing, will result only in smooth changes in the c-plots and T-plots that represent Δ. Smoothness of the plots constructed from given data on ρ may thus provide some check on the smoothness, but none on the accuracy of the assumed ρ_0 and ρ_i. To the extent that the analysis only smooths out the

contribution to Δ of the experimental errors in ρ, recommended values of $\rho(c,T)$ derived as

$$\rho(c,T) = \rho_0(c) + \bar{\rho}_i(c,T) + \Delta(c,T) \tag{A11}$$

will not contain errors due to the inaccuracies in ρ_0 or $\bar{\rho}_i$, these being cancelled out by the difference between the "exact" and the derived values of Δ. If, however, one constrains the derived Δ to have special properties known to be possessed by the exact Δ, this will no longer be the case. If, for instance, one imposes on the derived Δ's the condition that they vanish as $c \to 0$, as $c \to 1$, and as $T \to 0$, then errors in the assumed $\rho_0(c)$ will necessarily appear as errors in the derived $\rho(c,0K)$, and errors in the assumed $\rho_i^{(Ag)}$ and $\rho_i^{(Au)}$ will appear as errors in the derived $\rho(1,T)$ and $\rho(0,T)$, respectively. This is the best one can do unless the data under consideration justify a different extrapolation to the indicated limits — in which case one would in effect be using them to arrive at improved estimates of ρ_0 and of ρ_i.

In the present case, to extrapolate the alloy data smoothly: $c = 0, 1$ would yield values of the Δ's that are negative, and values of $\rho(0,T)$ and $\rho(1,T)$ that are unacceptably low. The plots of Δ in figure A-6 have therefore been constructed subject to the condition that the Δ's vanish as $c \to 0,1$. The possibility of removing the somewhat ill-defined minima near the ends of the curves, by reinterpretation of the data for $c = 0.05$, 0.1, 0.9 and 0.95, has been examined. The minima for small c can be removed by changing the corrections discussed above, while maintaining the smoothness of cross-plots, but this cannot be done with the minima for large c. The initial and most natural interpretation of the data is that presented in figure A-6.

An estimate of the constructional uncertainties remaining in the Δ's of figure A-6, after the full cross-plotting procedure, is given in table A-3; to these should be added any systematic errors not removed in the reconciling of high-T and low-T data.

Table A-3. Estimated Uncertainties in the Final Values of Δ

T,K	Uncertainty in Δ, $10^{-8}\Omega m$ Mole Fraction of Silver 0.01	0.03-0.97	0.99
100	0.005	0.015	0.01
200	0.005	0.02	0.01
400	0.02	0.03	0.02
600	0.025	0.04	0.02
800	0.03	0.06	0.03
1000	0.04	0.08	0.04
1200	0.05	0.10	0.05

The uncertainties in the values of ρ computed using eq (A11) have been estimated as follows. For the more concentrated alloys, c or 1-c equal to or greater than 0.05 $10^{-8}\Omega m$, the estimated error has been taken to be the estimated error in ρ_0 (in the first row of table A-4) plus twice the estimated constructional error. Inclusion of the first term reflects the doubt that the uncertainty in ρ_0 has been much reduced in the cross-plotting, and the doubling of the second term is intended to allow for systematic errors not removed in that process. For the most dilute alloys, the estimated error has been taken to be the estimated constructional error in Δ, plus the uncertainty in ρ_0, plus the uncertainty in the ρ_i of the pure solvent metal (first or last column of table A-4). The estimated uncertainties are shown in table A-4, both in absolute terms, and as a percentage of the estimated ρ.

The low estimates of errors for the concentrated alloys, $0.3 \le c \le 0.7$, reflect some optimism that the correlation of high-T and low-T data have reduced (by about 50%) the errors estimated by Iyer and Asimow for the high temperature data; the percentage error in ρ due to the uncertainty in Δ also tends to be small because ρ is itself so large. The percentage uncertainty is decidedly larger for the more dilute (c = 0.01-0.03) alloys, for which observations are entirely lacking for T >373 K, and interpolations of Δ are relatively insecure.

Table A-4. Estimated Uncertainties in the Recommended Values for the Electrical Resistivity of Gold-Silver Alloy System.

T,K	Uncertainty in ρ, 10^{-8} Ωm and % (in parentheses)												
	Mole Fraction of Silver												
	0.00	0.01	0.03	0.05	0.10	0.30	0.50	0.70	0.90	0.95	0.97	0.99	1.00
0	0	0.01	0.03	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.01	0
50	0.004 (2.0)	0.019 (3.6)	0.039 (3.5)	0.058 (3.5)	0.058 (1.9)	0.058 (0.8)	0.058 (0.6)	0.058 (0.7)	0.058 (1.7)	0.058 (3.1)	0.049 (4.2)	0.019 (3.9)	0.004 (4.0)
100	0.008 (1.3)	0.028 (2.9)	0.053 (3.4)	0.065 (3.0)	0.065 (1.9)	0.065 (0.8)	0.065 (0.7)	0.065 (0.8)	0.065 (1.7)	0.065 (3.0)	0.066 (4.4)	0.026 (3.3)	0.006 (1.5)
200	0.015 (1.0)	0.035 (2.0)	0.055 (2.3)	0.07 (2.4)	0.07 (1.6)	0.07 (0.8)	0.07 (0.7)	0.07 (0.8)	0.07 (1.6)	0.07 (2.5)	0.08 (3.7)	0.035 (2.5)	0.010 (1.0)
300	0.011 (0.5)	0.051 (2.0)	0.066 (2.1)	0.08 (2.1)	0.08 (1.6)	0.08 (0.9)	0.08 (0.7)	0.08 (0.8)	0.08 (1.6)	0.08 (2.3)	0.09 (3.3)	0.05 (2.5)	0.010 (0.6)
400	0.03 (1.0)	0.08 (2.4)	0.09 (2.3)	0.09 (2.0)	0.09 (1.5)	0.09 (0.9)	0.09 (0.7)	0.09 (0.8)	0.09 (1.6)	0.09 (2.2)	0.11 (3.3)	0.07 (2.7)	0.02 (0.9)
600	0.10 (2.1)	0.16 (3.1)	0.17 (3.0)	0.10 (1.6)	0.10 (1.3)	0.10 (0.9)	0.10 (0.7)	0.10 (0.8)	0.10 (1.3)	0.10 (1.9)	0.16 (3.5)	0.10 (2.6)	0.05 (1.4)
800	0.15 (2.2)	0.22 (3.2)	0.24 (3.2)	0.11 (1.4)	0.11 (1.2)	0.11 (0.8)	0.11 (0.7)	0.11 (0.8)	0.11 (1.3)	0.11 (1.7)	0.22 (3.7)	0.14 (2.7)	0.07 (1.4)
1000	0.22 (2.5)	0.31 (3.4)	0.33 (3.5)	0.13 (1.3)	0.13 (1.1)	0.13 (0.8)	0.13 (0.8)	0.13 (0.9)	0.13 (1.3)	0.13 (1.6)	0.29 (3.9)	0.19 (2.9)	0.10 (1.6)
1200	0.33 (2.9)	0.44 (3.9)	0.46 (3.9)	0.15 (1.2)	0.15 (1.1)	0.15 (0.8)	0.15 (0.8)	0.15 (0.9)	0.15 (1.3)	0.15 (1.5)	0.36 (4.0)	0.24 (2.9)	0.13 (1.6)

5.2. Methods for the Measurement of Electrical Resistivity.

At the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) of Purdue University, the experimental methods for the measurement of electrical resistivity have been classified into various categories according to a similar scheme used by CINDAS for the classification of methods for the measurement of thermal conductivity [399, pp. 13a-25a]. This classification scheme of CINDAS is presented below. Note that the letters in parentheses following the respective methods are the code letter used in the "Method Used" column of the Table of Measurement Information for indicating the experimental methods used by the various authors.

Methods for the Measurement of Electrical Resistivity

A. Steady-State Methods

1. Voltmeter and ammeter direct reading method (V) [400, p. 159; 401, pp. 244-5]
2. Direct-current potentiometer method (A) [19, pp. 151-8]
   a. 4-probe potentiometer method
3. Direct-current bridge methods (B) [19, pp. 144-51]
   a. Kelvin double bridge method
   b. Mueller bridge method
   c. Wheatstone bridge method
4. Van der Pauw method (P) [402,403]
5. Galvanometer amplifier method (G) [12, pp. 159-62]

B. Non-stead-state Methods

1. Periodic current method
   a. Direct connection to sample
      (1) Alternating-current potentiometer method (C) [19, pp. 161-2]
      (2) Alternating-current bridge method (D) [19, p. 162]
   b. No connection to sample
      (1) Mutual inductance method (M) [404]
      (2) Self-inductance method (S) [405]
      (3) Rotating field method (R) [406]
2. Non-periodic current method
   a. Direct connection to sample
      (1) Transient (subsecond) method (T) [407]
   b. No connection to sample
      (1) Eddy current decay method (E) [408; 19, p. 103]

5.3. Conversion Factors for the Units of Electrical Resistivity

The recommended values and experimental data for the electrical resistivity of alloys tabulated in this work are in the units: 10^{-8} Ω m. Conversion factors for the units of electrical resistivity, which may be used to convert the values given in (10^{-8} Ω m) to values in other units, are given in table A-5.

Table A-5. Conversion Factors for the Units of Electrical Resistivity

Units to Convert to	Multiply the Value Given in (10^{-8} Ω m) by
ohm-meter (Ω m)	1×10^{-8}
ohm-centimeter (Ω cm)	1×10^{-6}
ohm-inch (Ω in.)	3.937×10^{-7}
ohm-foot (Ω ft)	3.281×10^{-8}
microohm-centimeter (μΩ cm)	1
abohm-centimeter (abΩ cm)	1×10^{3}
statohm-centimeter (statΩ cm)	1.113×10^{-18}
emu (= abΩ cm)	1×10^{3}
esu (= statΩ cm)	1.113×10^{-18}
ohm-circular mil per foot (Ω cmil ft^{-1})	6.015

Example: 1.000×10^{-8} Ω m = 3.937×10^{-7} Ω in..

6. REFERENCES

1. Ho, C.Y., Ackerman, M.W., Wu, K.Y., Oh, S.G., and Havill, T.N., "Thermal Conductivity of Ten Selected Binary Alloy Systems," J. Phys. Chem. Ref. Data, 7(3), 959-1177, 1978.

2. Matthiessen, A., "Electrical Resistivity of Alloys," Ann. Physik, 110, 190-221, 1860.

3. Matthiessen, A. and Vogt, C., "The Influence of Temperature on the Electrical Conductivity of Alloys," Ann. Physik, 122, 19-78, 1864.

4. Sondheimer, E.H., "The Theory of the Transport Phenomena in Metals," Proc. Roy. Soc. London, A203(1072), 75-98, 1950.

5. Sommerfeld, A. and Bethe, H., "Electron Theory of Metals," in Handbuch der Physik, Vol. 24/2, Springer-Verlag, Berlin, 333-622, 1933.

6. Mott, N.F. and Jones, H., The Theory of the Properties of Metals and Alloys, Claredon Press, Oxford, England, 1936; Dover Publications, New York, 326 pp., 1958.

7. Wilson, A.H., The Theory of Metals, Cambridge University Press, 1936; 2nd Edition, 346 pp., 1953.

8. Bardeen, J., "Electrical Conductivity of Metals," J. Appl. Phys., 11, 88-111, 1940.

9. Seitz, F., The Modern Theory of Solids, McGraw-Hill Book Co., New York, 698 pp., 1940.

10. Mott, N.F., "Recent Advances in the Electron Theory of Metals," Progr. Metal Phys., 3, 76-114, 1952.

11. Peierls, R.E., Quantum Theory of Solids, Oxford University Press, 229 pp., 1955.

12. MacDonald, D.K.C., "Electrical Conductivity of Metals and Alloys at Low Temperatures," in Handbuch der Physik, Vol. 14, Springer-Verlag, Berlin, 137-97, 1956.

13. Gerritsen, A.N., "Metallic Conductivity, Experimental Part," in Handbuch der Physik, Vol. 19, Springer-Verlag, Berlin, 137-226, 1956.

14. Jones, H., "Theory of Electrical and Thermal Conductivity in Metals," in Handbuch der Physik, Vol. 19, Springer-Verlag, Berlin, 227-315, 1956.

15. Dekker, A.J., Solid State Physics, Prentice-Hall, Inc., Englewood Cliffs, N.J., 540 pp., 1957.

16. Ziman, J.M., Electrons and Phonons, Oxford University Press, 554 pp., 1960.

17. Olsen, J.L., Electron Transport in Metals, Interscience Publishers, New York, 121 pp., 1962.

18. Rosenberg, H.M., Low Temperature Solid State Physics, Oxford University Press, 420 pp., 1963.

19. Meaden, G.T., Electrical Resistance of Metals, Plenum Press, New York, 218 pp., 1965.

20. Blatt, F.J., Physics of Electronic Conduction in Solids, McGraw-Hill Book Co., New York, 446 pp., 1968.

21. Allen, P.B. and Butler, W.H., "Electrical Conduction in Metals," Phys. Today, 31(12), 44-9, 1978.

22. Bloch, F., "On the Quantum Mechanics of Electrons in a Crystalline Lattice," Z. Physik, 52, 555-600, 1928.

23. Bloch, F., "The Electrical Resistance Law at Low Temperatures," Z. Physik, 59, 208-14, 1930.

24. Gruneisen, E., "The Dependence of the Electrical Resistance of Pure Metals on the Temperature," Ann. Physik, 16, 530-40, 1933.

25. Meissner, W., "Galvanic and Thermomagnetic Effects," Handbuch der Experimentelle Physik, Vol. 11, Part 2, 311-94, 1935.

26. White, G.K., Experimental Techniques in Low Temperature Physics, Clarendon Press, Oxford, 328 pp., 1959.

27. Howie, A., "The Electrical Resistivity of Stacking Faults," Phil. Mag., Ser. 8, 5(51), 251-71, 1960.

28. Sondheimer, E.H. and Wilson, A.H., "The Theory of the Magneto-Resistance Effects in Metals," Proc. Roy. Soc. London, A190(1023), 435-55, 1947.

29. Dugdale, J.S. and Basinski, Z.S., "Matthiessen's Rule and Anisotropic Relaxation Times," Phys. Rev., 157(3), 552-60, 1967.

30. Ziman, J.M., "Approximate Calculation of the Anisotropy of the Relaxation Time of the Conduction Electrons in the Noble Metals," Phys. Rev., 121(5), 1320-4, 1961.

31. Campbell, I.A., Fert, A., and Pomeroy, A.R., "Evidence for Two Current Conduction Iron," Phil. Mag., Ser. 8, 15(137), 977-83, 1967.

32. Fletcher, R. and Grieg, D., "The Lattice Thermal Conductivity of Some Palladium and Platinum Alloys," Phil. Mag., 16(140), 303-15, 1967.

33. Bass, J., "Deviations from Matthiessen's Rule," Adv. Phys., 21(91), 431-604, 1972.

34. Cimberle, M.R., Bobel, G., and Rizzuto, C., "Deviations from Matthiessen's Rule at Low Temperatures: An Experimental Comparison Between Various Metallic Alloy Systems," Adv. Phys., 23(4), 639-71, 1974.

35. Nordheim, L., "The Electron Theory of Metals," Ann. Physik, 9(5), 607-78, 1931.

36. Norbury, A.L., "The Electrical Resistivity of Dilute Metallic Solid Solutions," Trans. Faraday Soc., 16, 570-96, 1921.

37. Linde, J.O., "Electrical Properties of Dilute Mixed Crystal Alloys. I. Gold Alloys," Ann. Physik, 10, 52-70, 1931.

38. Linde, J.O., "Electrical Properties of Dilute Solid Solution Alloys. II. Resistivity of Silver Alloys," Ann. Physik, 14, 353-66, 1932.

39. Linde, J.O., "Electrical Properties of Dilute Mixed Crystal Alloys. III. Resistance of Copper- and Gold Alloys. Regularity of Increase of Resistance," Ann. Physik, 15, 219-48, 1932.

40. Mott, N.F., "The Electrical Resistance of Dilute Solid Solutions," Proc. Camb. Phil. Soc., 32, 281-90, 1936.

41. Damask, A.C., "Some Resistivity Effects of Short-Range Order in Alpha-Brass," J. Appl. Phys., 27(6), 610-6, 1956.

42. Damask, A.C., "Residual Resistivity vs. Short-Range Order in 75% Copper-25% Gold Alloy," J. Phys. Chem. Solids, 1(1/2), 23-6, 1956.

43. Korevaar, B.M., "The Influence of Lattice Defects on the Electrical Resistivity of a Gold-Copper Alloy - 7 at.% Copper," Acta Metallurgica, 6(9), 572-9, 1958.

44. Mott, N.F., "A Discussion of the Transition Metals on the Basis of Quantum Mechanics," Proc. Phys. Soc. (London), 47, 571-88, 1935.

45. Coles, B.R. and Taylor, J.C., "The Electrical Resistivities of the Palladium-Silver Alloys," Proc. Roy. Soc., A267(1328), 139-45, 1962.

46. Dugdale, J.S. and Grénault, A.M., "The Low Temperature Transport Properties of the Palladium-Silver Alloy Series," Phil. Mag., Ser. 8, 13(123), 503-13, 1966.

47. Vuillemin, J.J. and Priestley, M.G., "De Haas-Van Alphen Effect and Fermi Surface in Palladium," Phys. Rev. Letters, 14(9), 307-9, 1965.

48. Mott, N.F. and Stevens, K.W.H., "The Band Structure of the Transition Metals," Phil. Mag., Ser. 8, 2(20), 1364-86, 1957.

49. Coles, B.R., "Spin-Disorder Effects in the Electrical Resistivities of Metals and Alloys," Adv. Phys., 7(8), 40-71, 1958.

50. Matula, R.A., "Electrical Resistivity of Copper, Gold, Palladium, and Silver," J. Phys. Chem. Ref. Data, 8(4), 1147-298, 1979.

51. Chi, T.C., "Electrical Resistivity of Alkaline Earth Elements," J. Phys. Chem. Ref. Data, 8(2), 439-97, 1979.

52. Chu, T.K. and Ho, C.Y., "Electrical Resistivity of Chromium, Cobalt, Iron, and Nickel," Purdue University, CINDAS Report to NBS, in preparation.

53. Chu, T.K. and Ho, C.Y., "Electrical Resistivity of Molybdenum, Tungsten, and Zinc," Purdue University, CINDAS Report to NBS, in preparation.

54. Chi, T.C. and Ho, C.Y., "Electrical Resistivity of Aluminum, Manganese, Vanadium, and Zirconium," Purdue University, CINDAS Report to NBS, in preparation.

55. Smith, A.W., "The Thermal Conductivities of Alloys," Ohio State Univ., Eng. Expt. Sta. Bull., 31, 5-61, 1925.

56. Griffiths, E. and Schofield, F.H., "The Thermal and Electrical Conductivity of Some Aluminum Alloys and Bronzes," J. Inst. Metals, 39, 337-74, 1928.

57. Gaudig, W. and Warlimont, H., "Direct Observations of the Short-Range Order and of a Stable Superlattice Phase in Alpha Copper-Aluminum Alloys," Z. Metallk, 60(5), 488-98, 1969.

58. Panin, V.Ye., Zenkova, E.K., and Fadin, V.P., "Study of the Ordering Effect in the Alloy Cu-Al. I. Homogeneous Solid Solutions," Fiz. Met. Metall., 13(1), 86-92, 1962; Engl. transl.: Phys. Met. Metall., 13(1), 76-81, 1962.

59. Panin, V.Ye., Fadin, V.P., and Solov'yev, L.A., "Order in Cu-Al Alloys. II. Alloys Close to the Solubility Boundary," Fiz. Met. Metall., 13(2), 219-24, 1962; Engl. transl.: Phys. Met. Metall., 13(2), 59-62, 1962.

60. Hibbard, W.R., Jr., "The Effect of Cold Work on the Electrical Resistivity of Copper Solid Solution Alloys," Acta Metall., 7(8), 565-74, 1959.

61. Wechsler, M.S. and Kernohan, R.H., "Neutron-Irradiation Effects on Copper Aluminum Alloys," Phys. and Chem. of Solids, 7(4), 307-26, 1958.

62. Gulyaev, A.P. and Trusova, E.F., "Mechanism of the Property Change in Solid Solutions," Zh. Tekhn. Fiz., 20(1), 66-78, 1950.

63. Linde, J.O., "The Effect of Cold-Work on the Electrical Resistivity of Alloys and the Law of Recovery," Appl. Sci. Res., Sec. B, 4(1-2), 73-86, 1954.

64. Smith, C.S. and Palmer, E.W., "Thermal and Electrical Conductivities of Copper Alloys," Am. Inst. Mining Metall. Eng., Tech. Publ. No. 648, 19 pp., 1935.

65. Pecijare, O. and Janssen, S., "Electricity - A Study on the Resistance of V_2 Phase of Alloys Cu-Al," Compt. Rend., 245, 1228-30, 1957.

66. Janssen, S. and Pecijare, O., "Electricity - A Study on the Resistance of Alloys Cu-Al," Compt. Rend., 244, 2017-20, 1957.

67. Köster, W. and Rothenbacher, P., "Conductivity and Hall Constant. 35. Influence of the Valency of B-Metals on the Change in Electrical Magnitude by Short Term Ordering in Ternary Alpha Mixed Crystals of Copper and Silver Alloys," Z. Metallk., 58(2), 93-8, 1967.

68. Hishiyama, Y., "Ordinary Transport Properties of the γ-Phase Alloys," J. Phys. Soc. Jpn., 22(2), 449-56, 1967.

69. Sinha, T.H.D. and Prasad, R.S., "Thermopower and Resistivity of Cu-Al Alloys," Indian J. Pure Appl. Phys., 9(4), 246-8, 1971.

70. Weinberg, I., "Phonon-Drag Thermopower in Copper-Aluminum and Copper-Silicon Alloys," Phys. Rev., 139(3A), A838-43, 1965.

71. Chu, T.K. and Lipschultz, F.P., "A Study of Cyclic Fatigue Damage in Copper-Aluminum Alloys by Thermal Conductivity Measurements," J. Appl. Phys., 43(6), 2505-10, 1972.

72. Chu, T.K. and Lipschultz, F.P., "A Study of Cyclic Fatigue Damage in Copper-Aluminum Alloys by Thermal Conductivity Measurements," AFOSR-TR-72-0409, 21 pp., 1972.

73. Salter, J.A.M. and Charsley, P., "The Effect of Grain Size on the Lattice Thermal Conductivity of Copper Aluminum Alloys," Phys. Status Solidi, 21, 357-68, 1967.

74. Charsley, P. and Salter, J.A.M., "The Lattice Thermal Conductivities of Annealed Copper-Aluminum Alloys," Phys. Status Solidi, 10(2), 575-83, 1965.

75. Kusunoki, M. and Suzuki, H., "Lattice Thermal Conductivity of Deformed Copper Aluminum Alloy Crystals at Low Temperatures," J. Phys. Soc. Japan, 26(4), 932-8, 1969.

76. Lindenfeld, P. and Pennebaker, W.C., "Lattice Conductivity of Copper Alloys," Phys. Rev., 127(6), 1881-9, 1962.

77. Kapoor, A., Rowlands, J.A., and Woods, S.B., "Lattice Thermal Conductivity of Cold-Worked Noble-Metal Alloys Between 0.5 and 4 K," Phys. Rev., B9(4), 1223-9, 1974.

78. Mitchell, M.A., Klemens, P.G., and Reynolds, C.A., "Lattice Thermal Conductivity of Plastically Deformed Copper Plus 10 Atomic Percent Aluminum Specimens in the Temperature Range 1-4 K," Phys. Rev., B3(4), 1119-30, 1971.

79. Mannchen, W., "Heat Conductivity, Electrical Conductivity and the Lorenz Number for a Few Light-Metal Alloys," Z. Metallkde., 23, 193-6, 1931.

80. Grard, C. and Villey, J., "On the Thermal Conductivity of Some Light Alloys," Compt. Rend., 185, 856-8, 1927.

81. Elflein, M., "Thermal and Electrical Conductivity of Cast Al Alloys with Especial Attention to Self-Aging Alloys," Forsch. Metallk. Röntgen., 23, 63 pp., 1937.

82. Turnbull, D., Rosenbaum, H.S., and Treaftis, H.N., "Kinetics of Clustering in Some Aluminum Alloys," Acta Metall., 8(5), 277-95, 1960.

83. Caplin, A.D. and Rizzuto, C., "Systematics of Matthiessen's Rule Breakdown at Low Temperatures," Aust. J. Phys., 24, 309-16, 1971.

84. Bollenrath, F. and Hank, V.Z., "Electrical Resistivity of Aluminum + Copper Alloy," Z. Metallkunde, 39, 106-8, 1948.

85. Robinson, A.T. and Dorn, J.E., "Effect of Alloying Elements on the Electrical Resistivity of Aluminum Alloys," Trans. AIME, J. Metals, 457-60, 1951.

86. Caplin, A.D. and Rizzuto, C., "Breakdown of Matthiessen's Rule in Aluminum Alloys," J. Phys. C, 3(6), L117-20, 1970.

87. Korol'kov, A.M. and Shashkov, D.P., "Electrical Resistivity of Some Alloys in the Liquid State," Russ. Met. Fuels, 1, 49-54, 1962.

88. Gniewek, J.J. and Wasik, C.A., "Electrical Resistivity and Hall Coefficient of $CuAl_2$," J. Appl. Phys., 42(5), 2151, 1971.

89. Watanabe, K. and Katsui, A., "Temperature Dependencies of Resistivity and Hardness of $CuAl_2$," J. Jap. Inst. Metals, 32(8), 808, 1968.

90. Leaver, A.D.W. and Charsley, P., "Low Temperature Lattice Thermal Conductivity of Deformed Copper Alloys," J. Phys., 1F(1), 28-37, 1971.

91. Eretnov, K.I. and Lyubimov, A.P., "Viscosity and Electrical Resistance of Binary Melts with Electron Compounds in the Solid State," Ukr. Fiz. Zh., 12(2), 216-23, 1967.

92. Sidorova, T.S., Panin, V.Ye., and Bol'shanina, M.A., "Investigation of the Nature of Low-Temperature Transformations in Deformed Cu-Al Alloys," Fiz. Met. Metall., 14(5), 750-6, 1962; Engl. transl.: Phys. Met. Metall., 14(5), 97-103, 1962.

93. Scala, E. and Robertson, W.D., "Electrical Resistivity of Liquid Metals and of Dilute Liquid Metallic Solutions," Trans. Amer. Inst. Mining Eng., 197, 1141-7, 1953.

94. Vozdvizhenskii, V.M., "Microheterogeneities in Metal Alloys," Phys. Met. Metall. (USSR), 11(2), 151-3, 1961.

95. Aliev, N.A., "Relationship of the Thermal Conductivity of Copper-Aluminum Alloys to Their Structure," Trudy. Inst. Fiz. i Mat. Akad. Nauk, Azerb. SSR, Ser. Fiz., 6, 62-8, 1953.

96. Bradley, J.M. and Stringer, J., "Hall Effect Measurements in Aluminum Alloys," J. Phys. F, 4, 839-47, 1974.

97. Köster, W. and Rave, H.P., "Conductivity and Hall Constant. XIII. α-Copper-Aluminum Alloys," Z. Metall., 52(3), 158-67, 1961.

98. Koester, W. and Rave, H.P., "General Remarks on Mixed Crystal Alloys of Copper and Silver with B-Metals," Z. Metallk, 55(12), 750-62, 1964.

99. Idase, R., Heierberg, R., and Walkenhorst, W., "Thermal Conductivity of Aluminum and Aluminum-Magnesium Alloys," Aluminum, 22, 631-5, 1940.

100. Cordier, H. and Detert, K., "Investigation of the Dissociation Process at Low Temperatures in an Aluminum + 10 wt.% Mg Alloy," Z. Metallkd, 52(5), 321-8, 1961.

101. Seth, R.S. and Woods, S.B., "Electrical Resistivity and Deviations from Matthiessen's Rule in Dilute Alloys of Aluminum, Cadmium, Silver, and Magnesium," Phys. Rev. B (Solid State), 2(8), 2961-72, 1970.

102. Clark, A.F., Childs, G.E., and Wallace, G.H., "Low Temperature Electrical Resistivity of Some Engineering Alloys," Cry. Eng. Conf. (UCLA, Los Angeles, CA), 1-15, 1969.

103. Clark, A.F., Childs, G.E., and Wallace, G.H., "Electrical Resistivity of Some Engineering Alloys at Low Temperatures," Cryogenics, 10(4), 295-305, 1970.

104. Clark, A.F. and Tryon, P.V., "Material Variability as Measured by Low Temperature Electrical Resistivity," Cryogenics, 12(6), 451-61, 1972.

105. Staebler, J., "Electrical and Thermal Conductivity and the Number of Wiedemann Franz of Light Metals and Magnesium Alloys," Tech Hochschule (of Breslau), Wroclaw, Poland, Ph.D. Thesis, 35 pp., 1929.

106. Powell, R.W., Hickman, M.J., and Tye, R.P., "The Thermal and Electrical Conductivity of Magnesium and Some Magnesium Alloys," Metallurgia, 70(420), 159-63, 1964.

107. Hedgcock, F.T. and Muir, W.B., "Influence of Lattice Scattering on Matthiessen's Rule in Dilute Binary Magnesium Alloys," Phys. Rev., 136(2A), A561-8, 1964.

108. Doyama, M., Koehler, J.S., Lwin, Y.N., Ryan, E.A., and Shaw, D.G., "Annealing Study of Dilute Aluminum Alloys Electron Irradiated at Liquid-Nitrogen Temperature," Phys. Rev. B, Ser. 3, 3(4), 1069-81, 1971.

109. Materials in Design Engineering, "Properties of Materials: Nonferrous Metals," Materials in Design Engineering, 50, 98-141, 1959.

110. Täubert, P., Thom, F., and Gammert, U., "The Lattice Heat Conductivity of Aluminum Alloys During Age-Hardening," Cryogenics, 13(3), 147-9, 1973.

111. Romanova, O.V. and Persion, Z.V., "Effect of Some Alloying Elements on Aluminum Electric Conductivity," Ukr. Fiz. Zh., 18(6), 1030-2, 1973.

112. Rapp, O. and Fogelholm, R., "Resistivity of Dilute Alloy AlMg and AlMn Between 0 and 100°C a Generalized Approach," Solid State Commun., 15, 1291-4, 1974.

113. Blatt, F.J., "Thermoelectric Power of Magnesium and Magnesium Alloys," Helv. Phys. Acta, 41(617), 693-700, 1968.

114. Collings, E.W., Hedgcock, F.T., Muir, W.B., and Muto, Y., "Magnetic and Electrical Properties of Some Ternary Mg-Mn-Al Alloys at Low Temperatures," Philos. Mag., 10(103), 159-67, 1964.

115. Kikuchi, R., "The Thermal and Electrical Conductivities of Magnesium Alloys," Kinzoku No Kenkyu, 9(6), 239-43, 1932.

116. Matsuda, T. and Sato, T., "Hall Coefficient of Aluminum Rich Alloys," J. Phys. Soc. Jpn., 21(8), 1494-503, 1966.

117. Salkovitz, E.I., Schindler, A.I., and Kammer, E.W., "Transport Properties of Dilute Binary Magnesium Alloys," Phys. Rev., 105(3), 887-96, 1957.

118. Steeb, S. and Wörner, S., "Atomic Distribution and Some Physical Properties of Molten Aluminum-Magnesium Alloys," Z. Metallkd., 56(11), 771-5, 1965.

119. Hirabayashi, M., "Electrical Resistivity and Superstructure of $CuAu_3$," J. Phys. Soc. Jpn., 14(3), 262-73, 1959.

120. Sato, H., "Electrical Resistivity of Au_3Cu at Low Temperatures," Phys. Rev., 106(4), 674-5, 1957.

121. Yonemitsu, K. and Sato, T., "Variation of Hall Coefficient of Some Non-Ferromagnetic Superlattice Alloys," J. Phys. Soc. Jpn., 13(9), 998-1004, 1958.

122. Johansson, C.H. and Linde, J.O., "Radiographic and Electric Investigation of Cu-Au Systems," Ann. Phys. (Leipzig), 25(1), 1-49, 1936.

123. Borelius, G., Johansson, C.H., and Linde, J.O., "The Lattice Structure-Transformation in Metallic Mixed Crystals," Ann. Phys. (Leipzig), 86, 291-304, 1928.

124. Passaglia, E. and Love, W.F., "Electrical Resistance of Copper-Gold Alloys at Low Temperature," Phys. Rev., 98(4), 1006-10, 1955.

125. Tainsh, R.J. and White, G.K., "Lattice Thermal Conductivity of Copper-and-Silver Alloys at Low Temperatures," Phys. Chem. Solids, 23(9), 1329-35, 1962.

126. Linde, J.O., "Electric Properties of Dilute Solid Solution Alloys. III. Resistance of Cu-Au Alloys: Regularity of Resistance Increases," Ann. Phys. (Leipzig), 15, 219-48, 1932.

127. Roll, A. and Motz, H., "The Electrical Resistivity of Metallic Melts. III. The Electrical Resistivity of Alloy Melts of the Mixed Crystal Systems Silver-Gold and Copper-Gold as Well as the Eutectic Systems Silver-Copper, Tin-Zinc and Aluminum-Zinc," Z. Metallkd., 48(9), 495-502, 1957.

128. Grüneisen, E. and Reddemann, H., "Electronic and Lattice Conduction of Heat in Metals," Ann. Phys. (Leipzig), 20, 843-77, 1934.

129. Kemp, W.R.G., Klemens, P.G., and Tainsh, R.J., "Lattice Thermal Conductivity of Some Copper Alloys," Aust. J. Phys., 10, 454-61, 1957.

130. Sedström, E., "Peltier-Heat, Together with Thermal and Electrical Conductivities of Several Metallic Solid Solutions," Ann. Phys. (Leipzig), 59, 134-44, 1919.

131. Röhl, H., "The Elastic Properties of Mixed-Crystals Au-Cu and Au-Pd and the Alloys Cu_3Pt, Cu_3Pd, and CuPd," Ann. Phys. (Leipzig), 18(5), 155-68, 1933.

132. Pospisil, V., "Investigation of the Au-Cu System by Measuring Its Resistivity at Low Temperatures," Ann. Phys. (Leipzig), 18(5), 497-514, 1933.

133. Jones, F.W. and Sykes, C., "Atomic Rearrangement Process in the Copper Gold Alloy Cu_3Au II," Proc. R. Soc. London, A166, 376-90, 1938.

134. Davis, T.H. and Rayne, J.A., "Specific Heat and Residual Resistivity of Binary and Ternary Noble-Metal Alloys," Phys. Rev., B6(8), 2931-42, 1972.

135. Huray, P.G., Roberts, L.D., and Thomson, J.O., "Study of the Cu-Au and Ag-Au Alloy Systems as a Function of Composition and Order Through the Use of the Mössbauer Effect for ^{197}Au," Phys. Rev., B4(7), 2147-61, 1971.

136. Ascoli, A., Bergamini, P., and Queirolo, G.T., "Impurity-Vacancy Binding Energy Obtained from Equilibrium Resistivity of Cu-Doped Au," Scripta Metall., 6, 641-6, 1972.

137. Damon, D.H., Mathur, M.P., and Klemens, P.G., "Phonon-Assisted Impurity Scattering in Gold Alloys," Phys. Rev., 176(3), 876-85, 1968.

138. Sedström, E., "On the Knowledge of Gold-Copper Alloys," Ann. Phys. (Leipzig), 75, 549-55, 1924.

139. Eitel-McCullough, Inc., "Metallurgical Research and Development for Ceramic Electron Devices," Quarterly Report No. 5, AD 428 529, 38-9, 1963.

140. Broniewski, W. and Wesolowski, K., "On the Structure of Gold-Copper Alloys," C. R. Hebd. Seances Acad. Sci., 198, 370-2, 1934.

141. Lengeler, B., Schilling, W., and Wenzl, H., "Deviations from Matthiessen's Rule and Longitudinal Magnetoresistance in Copper," J. Low Temp. Phys., 2(1), 59-86, 1970.

142. Köster, W. and Schüle, W., "Conductivity and Hall Coefficient. IV. Copper-Nickel Alloys," Z. Metallkd., 48, 592-4, 1957.

143. Schüle, W. and Kehrer, H.P., "Studies in Copper-Nickel System with Regard to Vacancies and Precipitation by Means of Electrical Resistivity," Z. Metallkd., 52(3), 168-79, 1961.

144. Hedman, L.E. and Mattuck, R.D., "Effect of Heat Treatment and Plastic Deformation on the Paramagnetic Susceptibility of Copper-Nickel Alloys," J. Phys. Chem. Solids, 23, 955-61, 1962.

145. Robbins, C.G., Claus, H., and Beck, P.A., "Magnetism in Ni-Cu Alloys," Phys. Rev. Lett., 22(24), 1307-10, 1969.

146. Mozer, B., Keating, D.T., and Moss, S.C., "Neutron Measurement of Clustering in the Alloy CuNi," Phys. Rev., 175(3), 868-76, 1968.

147. Hicks, T.J., Rainford, D., Kouvel, J.S., Low, G.G., and Comly, J.B., "Giant Moments in Nickel-Copper alloys Near the Critical Composition," Phys. Rev. Lett., 22(11), 531-4, 1969.

148. Kussmann, A. and Wollenberger, H., "Influence of Thermal Treatment and Deformation on the Paramagnetic Behavior of Nickel-Copper Alloys," Z. Metallkd., 54(9), 521-4, 1963.

149. Furukawa, G.T., Reilly, M.L., and Saba, W.G., "Electrical Resistances of Wires of Low Temperature Coefficient of Resistance Useful in Calorimetry, 10-380 K," Rev. Sci. Instrum., 35(1), 113-4, 1964.

150. Rode, V.E., Blyushke, A., Finkel'berg, S.A., and Leichenko, A.I., "Temperature Dependence of the Susceptibility of Ni-Cu Alloys," Sov. Phys.-JETP, 35(3), 568-70, 1972.

151. Ahmad, H.M. and Greig, D., "Electrical Resistivity and Thermopower of Nicke-Copper Alloys," J. Phys. (Paris) Colloq., 4, 223-6, 1974.

152. Ahern, S.A., Martin, M.J.C., and Sucksmith, W., "The Spontaneous Magnetization of Nickel + Copper Alloys," Proc. R. Soc. London, 248A, 145-52, 1958.

153. Ahern, S.A. and Sucksmith, W., "Saturation Magnetization in Copper-Nickel Alloys," Proc. Phys. Soc., London, 69B(10), 1050-2, 1956.

154. Jackson, P.J. and Saunders, N.H., "Electrical and Thermal Conductivity of Nickel-Copper Alloys in the Neighborhood of the Curie-Point," Phys. Lett., 28A(1), 19-20, 1968.

155. Alder, M., University of Zurich, Ph.D. Thesis, 1916; as reported by Néel, L., "Magnetic Properties of the Metallic State and Energy of Interaction Between Magnetic Atoms," Ann. Phys. (Paris), 5, 232-79, 1936.

156. Meyer, A.J.P. and Wolff, C., "The Magnetic Properties of a Series of Nickel-Copper Alloys," C. R. Hebd. Seances Acad. Sci., 246(4), 567-9, 1958.

157. Torkar, K. and Goetz, H., "Magnetic Analysis of Copper-Nickel Sinter Bodies," Z. Metallkd., 45(5), 371-7, 1955.

158. Yao, Y.D., "Electrical Resistivity of Nickel-Rich Nickel-Copper Alloys Between 78 and 700 K," Annual Rept. Inst. Phys., Acad. Sinica, 8, 11-7, 1978.

159. Bagguley, D.M.S. and Heath, M., "Ferromagnetic Resonance in a Series of Alloys. I. Binary Alloys of Nickel with Copper, Tungsten, Cobalt, and Chromium," Proc. Phys. Soc., London, 90, Part 4, no. 570, 1029-45, 1967.

160. Standley, K.J. and Reich, K.H., "Ferromagnetic Resonance in Nickel and in Some of Its Alloys," Proc. Phys. Soc., London, 68B(10), 713-22, 1955.

161. Bloch, D. and Pauthenet, R., "Magnetic Properties Under Pressure of Some Transition Metal Alloys," J. Appl. Phys., 36(3), 1229-30, 1965.

162. Belov, K.P. and Goriaga, A.N., "Influence of the Structural Characteristics of Ferromagnets on the Temperature Dependence of the Spontaneous Magnetization," Bull. Acad. Sci. USSR, Phys. Ser. (Engl. Transl.), 21, 1043-50, 1957.

163. Van Elst, H.C., Lubach, B., and Van den Berg, G.J., "The Magnetization of Some Nickel Alloys in Magnetic Fields up to 15 kOe Between 0 and 300 K," Physica, 28(12), 1297-317, 1962.

164. Svensson, B., "Ferromagnetic Resistivity Increase of Copper-Nickel Alloys," Ann. Phys. (Leipzig), Ser. 5, 25(5), 263-71, 1936.

165. Weiss, R.J., "The Origin of the Invar Effects," Army Material Research Agency MRL Rept. 133, 15 pp., 1963. [AD 415 635]

166. Yamasawa, K. and Murakami, K., "Experimental Study of Basic Characteristics of Temperature-Sensitive Magnetic Materials," Tohoku Univ. Technol. Rept., 38(1), 225-36, 1973.

167. Wheeler, M.A., "The Paramagnetic Susceptibility of Copper-Nickel and Zinc-Nickel Alloys," Phys. Rev., 56, 1137-45, 1939.

168. Marian, V., "The Ferromagnetic Curie Points and Absolute Saturation of Several Nickel Alloys," Ann. Phys. (Paris), 7, 459-527, 1937.

169. Sousa, J.B., Chaves, M.R., Pinheiro, M.F., and Pinto, R.S., "Electrical Resistivity in Ferromagnetic Nickel-Copper Alloys Near the Curie Point," J. Low Temp. Phys., 18(1-2), 125-37, 1975.

170. Skoskiewicz, T. and Baranowski, B., "Low Temperature Minimum of the Electrical Resistance in Ni-Cu and Ni-Cu-H Alloys," Solid State Commun., 7, 647-9, 1969.

171. Crangle, J. and Butcher, P.J.L., "Observation of Resistance Minima in Cu-Ni Alloys Near the Critical Concentration for Ferromagnetism," Phys. Lett., 32A(2), 80-1, 1970.

172. Houghton, R.W., Sarachik, M.P., and Kouvel, J.S., "Electrical Resistivity and Magnetoresistance of Paramagnetic Nickel-Copper Giant-Moment Alloys," Solid State Commun., 8(12), 943-5, 1970.

173. Houghton, R.W., Sarachik, M.P., and Kouvel, J.S., "Anomalous Electrical Resistivity and the Existence of Giant Magnetic Moments in Ni-Cu Alloys," Phys. Rev. Lett., 25(4), 238-9, 1970.

174. Kondorskii, E.I., Galkina, O.S., and Chernikova, L.A., "Electrical Resistance Maximum for Ferromagnets at Their Curie Points at Low Temperatures," Sov. Phys.-JETP, 11(2), 464-6, 1960.

175. Ahmad, H.M. and Greig, D., "High Temperature Resistance Minima in Concentrated Pd-Ag and Ni-Cu Alloys," Phys. Rev. Lett., 32(15), 833-5, 1974.

176. Eagen, C.F., "Resistivity and Magneto-Resistance of Dilute Solutions of Cr in Cu-Ni Alloys," Iowa State Univ., Ph.D. Thesis, 70 pp., 1972.

177. Eagen, C.F. and Legvold, S., "Resistivity and Magnetoresistance of Dilute Solutions of Cr in Cu-Ni Alloys," Phys. Rev., B6(5), 1830-8, 1972.

178. Legvold, S., Peterson, D.T., Burgardt, P., Hofer, R.J., Lundell, B., and Vyrostek, T.A., "Residual Resistivity and Aging-Clustering Effects of Cu-Rich Cu-Ni Alloys," Phys. Rev., B9(5), 2386-9, 1974.

179. Domenicali, C.A. and Christenson, E.L., "Effects of Transition Metal Solutes on the Electrical Resistivity of Copper and Gold Between 4 and 1200 Degrees K," J. Appl. Phys., 32(11), 2450-6, 1961.

180. Schroeder, P.A., Wolf, R., and Woollam, J.A., "Thermopowers and Resistivities of Silver-Palladium and Copper-Nickel Alloys," Phys. Rev., 138(1A), A105-11, 1965.

181. Bulow, C.L., "Properties of Copper Alloys at Cryogenic Temperatures," Electrical Design News, 9(6), 70-8, 1964.

182. Jowitz, A.E., "Cryogenics, Environment, Phenomena, Application," Electro-Technol., 68(3), 121-33, 1961.

183. Chang, H., "Electrical and Thermoelectric Properties of Some Metallic Thermoelectric Materials," Energy Conversion, 10(2), 65-72, 1970.

184. Pollock, D.D. and Finch, D.I., "Effects of Alloying Elements on the Electrical Properties of Manganin-Type Alloys," Trans. Amer. Inst. Min. Met. Eng., 206, 203-10, 1956.

185. Mikryukov, V.E., "Thermal and Electrical Properties of Copper Alloys," Vestnik Moskov Univ. Ser. Mat. Mekh. Astron. Fiz. Khim., 11(2), 53-70, 1956.

186. Kierspe, W., "Influence of Transition Elements on Thermal Conductivity of Copper," Z. Metallkd., 58(12), 895-902, 1967.

187. Dutta-Roy, S.K. and Subrahmanyam, A.V., "Hall Effect, Magnetic Resistivity, and Magnetic Susceptibility of Nickel and Nickel-Copper Alloys," Phys. Rev., 177(3), 1133-8, 1969.

188. Lecordier, J.C. and Colombani, A., "Electric Properties of Thin Films of a Copper-Nickel Alloy," C. R. Hebd. Seances Acad. Sci., Ser. A/B, 266(23), 1426-9, 1968.

189. Sager, G.F., "Investigation of the Thermal Conductivity of the System Copper-Nickel," Eng. Sci. Series, Rensselaer Polytech. Inst. Bull., 27, 3-48, 1930.

190. Barratt, T., "Thermal and Electrical Conductivities of Some of the Rarer Metals and Alloys," Proc. Phys. Soc., London, 26, 347-71, 1914.

191. Grüneisen, E. and Goens, E., "Investigations of Metal Crystals. V. Electric and Thermal Conductivity of Single Crystal and Polycrystalline Metals of the Cubic System," Z. Phys., 44, 615-42, 1927.

192. Jaeger, W. and Diesselhorst, H., "Heat Conduction, Electric Conduction, Heat Capacity, and Thermoelectrical EMF of Several Metals," Wiss. Abh. Phys.-Tech. Reichsanst., 3, 269-425, 1900.

193. Zimmerman, J.E., "Heat Conduction in Alloys and Semi-Conductors at Low Temperatures," Carnegie Institute of Technology, Ph.D. Thesis, 1951.

194. Estermann, I. and Zimmerman, J.E., "Effect of Lattice Defects on the Thermal Conductivity of Certain Alloys at Low Temperatures," Bull. Intern. Inst. Refrig. Annexe 1, 35-42, 1952.

195. Berman, R., "The Thermal Conductivity of Some Alloys at Low Temperatures," Philos. Mag., 42, 642-50, 1951.

196. Ellis, W.C., Morgan, F.L., and Sager, G.F., "The Thermal Conductivities of Copper, Nickel, and Some Alloys of Nickel," Eng. Sci. Series, Rensselaer Polytech. Inst. Bull., No. 21, 23 pp., 1928.

197. Grüneisen, E., "Thermal Conductivity of Metals and Their Relation to the Electrical Conductivity," Ann. Phys. (Leipzig), Ser. 4, 3, 43-74, 1900.

198. Mikryukov, V.E., "Thermal and Electrical Properties of Copper Alloys," Vestnik Moskov Univ. Ser. Mat. Mekh. Astron. Fiz. Khim., 12(2), 85-93, 1957.

199. Hulm, J.K., "The Thermal Conductivity of Copper-Nickel Alloy at Low Temperatures," Proc. Phys. Soc., London, Ser. B, 64, 207-11, 1951.

200. Telkes, M., "Solar Thermoelectric Generators," J. Appl. Phys., 25(6), 765-77, 1954.

201. Lerner, E. and Daunt, J.G., "Magnetoresistance Effect in Advance and Evanohm Wires at Low Temperatures in Fields up to 50 kG," Rev. Sci. Instrum., 35(8), 1069-70, 1964.

202. Harvey, A.R., Legvold, S., and Peterson, D.T., "Resistivity and Magnetoresistance of Dilute Solutions of Mn in Cu-Ni Alloys," Phys. Rev., B4(11), 4003-8, 1971.

203. Los, G.J. and Gerritsen, A.N., "Resistance and Magneto-Resistance of Dilute Alloys of Copper and Gold with Nickel at Low Temperatures," Physica, 23, 633-40, 1957.

204. Kondorskii, E.I., Galkina, O.S., and Chernikova, L.A., "Nature of Electrical Resistivity of the Ferromagnetic Metals at Low Temperatures," J. Appl. Phys., 29(3), 243-6, 1958.

205. Allison, F.E. and Pugh, E.M., "Temperature Dependence of the Hall Coefficient in Some Copper Nickel Alloys," Phys. Rev., 102, 1281-7, 1956.

206. Galkina, O.S. and Chernikova, L.A., "The Relation Between the Temperature Dependence of Electrical Resistance at Low Temperatures and the Galvanomagnetic Effect in Strong Magnetic Fields," Sov. Phys.-JETP, 11(1), 1-3, 1960.

207. Farrell, T. and Greig, D., "The Electrical Resistivity of Nickel and Its Alloys," Proc. Phys. Soc. J. Phys. C, 1, 1359-69, 1968.

208. Kondorskii, E.I., Galkina, O.S., and Chernikova, L.A., "Low-Temperature Resistivity of Nickel Alloys and Its Variation in Magnetic Fields," Acad. of Sci., USSR, Bull., Phys. Ser., 21, 1109-15, 1958.

209. Greig, D. and Harrison, J.P., "The Low Temperature Electrical Transport Properties of Nickel and Dilute Nickel-Copper Alloys," Philos. Mag., 12, 71-9, 1965.

210. Farrell, T. and Greig, D., "The Thermal Conductivity of Nickel and Its Alloys," J. Phys. C, Ser. 2, 2, 1465-73, 1969.

211. Yarbrough, D.W., Williams, R.K., and Graves, R.S., "Transport Properties of Concentrated Ag-Pd and Cu-Ni Alloys from 300-1000 K," Paper presented at the 16th Int. Therm. Cond. Conf., Chicago, IL, Nov. 7-9, 1979.

212. Greig, D. and Rowlands, J.A., "Electrical Resistivity of Dilute Nickel Alloys," Low Temp. Phys.-LT13 (Proc. 13th Int. Conf. Low Temp. Phys.), 4, 233-5, 1974.

213. Lihl, F. and Wildhack, H., "Recovery of Lattice Defects in Polycrystalline Copper, Nickel, and Copper-Nickel Alloys After Tensile Deformation at 78 K," Z. Metallkd., 62(2), 143-7, 1971.

214. Aoyama, S. and Ito, T., "Thermal Conductivity of Some Cu-Ni Alloys between 80 K and Room Temperature," Nippon Kinzoku Gakkaishi, 4, 3-7, 1940.

215. Erdmann, J.C. and Jahoda, J.A., "Temperature Dependence of the Lattice Thermal Conductivity of Copper-Nickel Alloys at Low Temperatures," in Thermal Conductivity: Proc. 7th Thermal Cond. Conf., NBS Spec. Publ. 302, 259-70, [illegible].

216. Erdmann, J.C. and Jahoda, J.A., "Thermal Conductivity of Copper-Nickel Alloys at 4.2 K," Boeing Sci. Res. Lab. Rept. D1-82-0333, 22 pp., 1964. [AD 600 457]

217. Gartner, H., Zrudsky, D.R., and Legvold, S., "Low Temperature Electrical Resistivity of Dilute Solutions of Fe in Cu-Ni Alloys," Solid State Commun., 8, 913-8, 1970.

218. Linz, R.J., Bowley, A.C., Klaffky, R.W., and Damon, D.H., "The Electrical and Thermal Conductivities of Cu-4, 10, and 20 at.% Ni from 1 to 25 K," IEEE Trans. Magn., MAG-11(2), 305-8, 1975.

219. Kaul, S.N., "Anisotropy in Low Field Transverse Magnetoresistivity of Nickel-Copper Alloys at Room Temperature," Indian J. Phys., 49, 143-54, 1975.

220. Van Elst, H.C. and Gorter, C.J., "The Ferromagnetic Anisotropy of the Specific Resistance of Some Nickel Alloys," Appl. Sci. Res., Ser. B, 4(1-2), 87-90, 1954.

221. Svensson, B., "Magnetic Susceptibility and Electrical Resistivity of Solid Solutions of Pd-Ag and Pd-Cu," Ann. Physik, Ser. 5, 14, 699-711, 1932.

222. Johansson, C.H. and Linde, J.O., "Lattice Structure and Electrical Conductivity of the Solid Solutions of Au-Cu, Pd-Cu, and Pt-Cu," Ann. Physik, 82(4), 449-78, 1927.

223. Pott, F.P., "Investigation of the Wiedemann-Franz-Lorenz Law for Ordered and Disordered Phases of a Range of Copper-Palladium Alloys," Z. Naturforsch., 13a(3), 215-21, 1958.

224. Köster, W. and Lang, W., "Several Physical Properties for Superstructures with Dislocations," Z. Metallkd., 49(9), 443-9, 1958.

225. Jaumot, F.E. and Sawatzky, A., "Order-Disorder and Cold-Work Phenomena in Cu-Pd Alloys," Acta Metall., 4, 118-44, 1956.

226. Otter, F.A., Jr., "Thermoelectric Power and Electrical Resistivity of Dilute Alloys of Mn, Pd, and Pt, in Cu, Ag, and Au," J. Appl. Phys., 27(3), 197-200, 1956.

227. Bäcklund, N., "Electrical Resistance of Some Noble-Metal Alloys at Liquid-Helium Temperatures," Phys. Chem. Solids, 7(1), 94-5, 1958.

228. Yonemitsv, K. and Sato, T., "Variation of Hall Coefficient of Some Non-ferromagnetic Superlattice Alloys," J. Phys. Soc. Jpn., 13(9), 998-1004, 1958.

229. Ugodnikova, L.A., Volkenshtein, N.V., and Tsiovkin, Yu.N., "Thermo-emf and Resistivity of Copper-Palladium Solid Solutions," Fiz. Met. Metalloved. Akad. Nauk SSSR Ural Filial, 31(3), 543-7, 1971.

230. Rennollet, G. and Seemann, H.J., "Influence of Temperature on the Hall Constant and the Electrical Conductivity of Copper-Palladium Alloys with Random and Ordered Atomic Distribution," Z. Angew. Phys., 28(3), 148-58, 1969.

231. Taylor, R., "Transformations in the Copper-Palladium Alloys," J. Inst. Metals, 54, 255-72, 1934.

232. Kim, M.J. and Flanagan, W.F., "The Effect of Plastic Deformation on the Resistivity and Hall Effect of Copper-Palladium and Gold-Palladium Alloys," Acta Metall., 15, 735-45, 1967.

233. Buynova, L.N., Syutkina, V.I., Shashkov, O.D., and Yakovleva, E.S., "Influence of Domain Size on the Properties of Copper-Palladium Alloys," Fiz. Met. Metalloved., 33(6), 1195-206, 1972; Engl. transl.: Phys. Met. Metallogr., USSR, 33(6), 67-77, 1972.

234. Holgersson, S. and Sedström, E., "Experimental Measurement of the Lattice Structure of Several Metal Alloys," Ann. Physik, 75(18), 143-62, 1924.

235. Sedström, E., "Several Physical Properties of Metallic Alloys," University of Stockholm, Ph.D. Thesis, 1924.

236. Mallory Metallurgical Company, "Electrical Contacts," Mallory, P.R. and Co., Inc., Bull. No. 3-25, 71 pp., 1964.

237. Massalski, T.B. and Kittl, J.E., "The Low Temperature Solid Solubility Limits of the α and β Phases in the Cu-Zn System," J. Aust. Inst. Met., 8(1), 91-7, 1963.

238. Shinoda, G. and Amano, Y., "The Eutectoid Transformation of the β' Phase in Cu-Zn Alloys," Trans. Jap. Inst. Met., 1(1), 54-7, 1960.

239. Argent, B.B. and Lee, K.T., "The Electrical Resistivities and Lattice Parameters of Copper-Gold-Zinc Alloys," Br. J. Appl. Phys., 15(12), 1523-8, 1964.

240. Henry, W.G. and Schroeder, P.A., "The Low-Temperature Resistivities and Thermopowers of Alpha-Phase Copper-Zinc Alloys," Can. J. Phys., 41(7), 1076-93, 1963.

241. Fairbank, H.A., "The Electrical Resistivity of Copper-Zinc and Copper-Tin Alloys at Low Temperature," Phys. Rev., 66(9/10), 274-81, 1944.

242. Smith, C.S., "Thermal Conductivity of Copper Alloys. I. Cu-Zn Alloys," Trans. AIME, 89, 84-106, 1930.

243. Takano, K., "Hall Coefficient of Beta-Phase Alloys," J. Phys. Soc. Jpn., 26(2), 362-70, 1969.

244. Tainsh, R.J. and White, G.K., "Lattice Thermal Conductivity of Copper- and Silver-Alloys at Low Temperatures," Phys. Chem. Solids, 23(9), 1329-35, 1962.

245. Crisp, R.S. and Henry, W.G., "The Temperature Dependence of the Characteristic Thermopowers of Zinc, Gallium, Germanium, and Arsenic in Copper and Silver," Philos. Mag., 11(112), 841-51, 1965.

246. Kemp, W.R.G., Klemens, P.G., Tainsh, R.J., and White, G.K., "The Electrical and Thermal Conductivities of Some Brasses at Low Temperatures," Acta Metall., 5, 303-9, 1957.

247. Kemp, W.R.G., Klemens, P.G., and Tainsh, R.J., "Lattice Thermal Conductivity of Copper Alloys: Effect of Plastic Deformation and Annealing," Philos. Mag., 4(43), 845-57, 1959.

248. Eucken, A. and Neumann, O., "Zur Kenntnis des Wiedemann-Franzschen Gesetzes. I," Z. Physik Chem., 111, 431-46, 1924.

249. Olsen, T., "Lattice Thermal Conductivity in Copper Alloys," J. Phys. Chem. Solids, 12(2), 167-74, 1960.

250. Gordon, J.E. and Amstutz, L.I., "A Brass Thermometry for Use in Determining Temperature Below 1 K," Cryogenics, 329-32, 1965.

251. Srivastava, B.N., Chatterjee, S., and Sen, S.K., "Thermal and Electrical Conductivities of Alloys at Low Temperatures," Indian J. Phys., 43, 213-22, 1969.

252. Maxwell, E., "Conductivity Loss Measurements at K-Band," MIT Radiation Laboratory, Report 854, 26 pp., 1946. [AD 24 458]

253. Domenicali, C.A. and Otter, F.A., "Thermoelectric Power and Electron Scattering in Metal Alloys," Phys. Rev., 95(5), 1134-42, 1954.

254. Crisp, R.S., Henry, W.G., and Schröder, P.A., "The Thermopowers and Resistivities of the Primary Solid Solutions of Zinc, Gallium, Germanium, and Arsenic in Copper," Philos. Mag., 10(106), 553-77, 1964.

255. Muto, Y. and Noto, K., "Magnetoresistivity Behavior of Some Dilute Cu-Fe, Cu-Mn, and Cu-Zn Alloys at Liquid Helium Temperatures," Can. J. Phys., 42, 15-25, 1964.

256. Fusfeld, H.I., "Effect of Cold Work and Anneal on Resistivity of Alpha Brass," J. Appl. Phys., 24(8), 1062-3, 1953.

257. Ayers, J.D. and Massalski, T.B., "A Kinetic Study of the β to α Massive Transformation in a Cu-Zn Alloy," Metall. Trans., 3(12), 3185-90, 1972.

258. Broom, T., "The Effect of Temperature of Deformation on the Electrical Resistivity of Cold-Worked Metals and Alloys," Proc. Phys. Soc. London, 65, 871-81, 1952.

259. Sato, T. and Noguchi, S., "Note on Some Properties of Gamma Brass," J. Phys. Soc. Jpn., 12(4), 335-9, 1957.

260. Martin, M.C., "Effect of Quenching on the Electrical Resistivity of a β-Brass Single Crystal," J. Appl. Phys., 34(6), 1835-6, 1963.

261. Aoyama, S. and Ito, T., "On the Thermal and Electrical Conductivities of Metals and Alloys at Low Temperatures. III. On Cu-Zn Alloys," Nippon Kinzoku Gakkai-Si, 4, 37-40, 1940.

262. Köster, W. and Schüle, W., "Conductivity and Hall-Constant. III. α-Copper-Zinc Alloy," Z. Metall., 48(11), 588-91, 1957.

263. Presnyakov, A.A., Dautova, L.I., and Klychnikov, Yu.F., "Anomalies in the Electrical Resistivity of Brasses and Aluminum Bronzes," Fiz. Met. Metall., 10(5), 676-9, 1961; Engl. Transl.: Phys. Met. Metall. (USSR), 10(5), 41-5, 1961.

264. Hansen, M., Constitution of Binary Alloys, McGraw-Hill Book Co., New York, NY, 1305 pp., 1958.

265. Nagasawa, A., Matsuo, Y., and Kakinoki, J., "Ordered Alloys of Gold-Palladium System. I. Electron Diffraction Study of Evaporated Au_3Pd Films," J. Phys. Soc. Jpn., 20(10), 1881-5, 1965.

266. Copeland, W.D. and Nicholson, M.E., "X-Ray Evidence of Short-Range Order in Au-Pd System," Acta Metall., 12, 321-2, 1964.

267. Iveronova, V.I. and Katsnel'son, A.A., "Existence of Short-Range Order in Gold-Palladium Alloys," Sov. Phys. Crystallogr. (Engl. Transl.), 9(4), 467-8, 1965.

268. Iveronova, V.I. and Katsnel'son, A.A., "Short-Range Order in a Gold-Palladium Alloy of Equiatomic Composition," Sov. Phys. Crystallogr. (Engl. Transl.), 11(4), 504-7, 1967.

269. Lin, W., Spruiell, J.E., and Williams, R.O., "Short-Range Order in a Gold-40.0 Atomic Percent Palladium Alloy," J. Appl. Crystallogr., 3, 297-305, 1970.

270. Devi, U., Rao, C.N., and Rao, K.K., "Effect of Temperature on the Lattice Parameter of a 58.98 at.% Gold-41.02 at.% Palladium Alloy," Acta Metall., 13(1), 44-5, 1965.

271. Köster, W. and Halpern, T., "Conductivity and Hall Constant. XXI. Gold-Palladium Alloys," Z. Metallkd., 52, 821-5, 1961.

272. Logie, H.J., Jackson, J., Anderson, J.C., and Nabarro, F.R.N., "Effect of Plastic Deformation on Resistivity of Gold-Palladium Alloys," Acta Metall., 9(8), 707-13, 1961.

273. Kim, M.J. and Flanagan, W.F., "The Recovery Kinetics of Deformed Copper-Palladium and Gold-Palladium Alloys," Acta Metall., 15(5), 753-64, 1967.

274. Haas, H. and Lücke, K., "On the Short-Range Order Formation in Gold-Palladium Alloys," Scr. Metall., 6(8), 715-20, 1972.

275. Lücke, K., Haas, H., and Schulze, H.A., "Equilibrium Values of Short Range Order in Gold-Silver and Gold-Palladium Alloys," J. Phys. Chem. Solids, 37, 979-87, 1976.

276. Rowland, T., Cusack, N.E., and Ross, R.G., "The Resistivity and Thermoelectric Power of the Palladium-Gold Alloy System," J. Phys. F, 4, 2189-202, 1974.

277. Kim, M.J., University of Washington, Ph.D. Thesis, 1966.

278. Kim, M.J. and Flanagan, W.F., "An Approximate Density of States Curve and Its Relation to the Measured Electrical Resistivity of Gold-Palladium Alloys," Acta Metall., 15(5), 747-52, 1967.

279. Hau, N.H., "The Transport Properties of Palladium-Gold Alloys," Ohio University, Ph.D. Thesis, 108 pp., 1966.

280. Conybeare, J.G.G., "The Resistance of Palladium and Palladium-Gold Alloys," Proc. Phys. Soc. London, 49, 29-37, 1937.

281. Laubitz, M.J. and Van der Meer, M.P., "High Temperature Transport Properties of Some Platinel Alloys," in Thermal Conductivity - Proc. Seventh Conf., NBS Spec. Publ. 302, 325-30, 1968.

282. Ugodnikova, D.A., Beilin, B.M., and Tsiovkin, Yu.Yu.N., "Observation of Palladium Clusters in the Alloy $Au_{0.6}Pd_{0.4}$," JETP Lett. (Engl. Transl.), 19(7), 234-6, 1974.

283. Bäcklund, N., "Electrical Resistance of Some Noble-Metal Alloys at Liquid-Helium Temperatures," Phys. Chem. Solids, 7(1), 94-5, 1958.

284. Köster, W. and Hagmann, D., "Conductivity and Hall Constant, XVI. The Solid Solutions of Palladium with Neighboring Elements in the Periodic System," Z. Metallkd., 52, 721-7, 1961.

285. Geibel, W., "Several Electrical and Mechanical Properties of Noble Metal Alloys. I," Z. Anorg. Chem., 69, 38-46, 1911.

286. Schulze, F.A., "The Thermal Conductivity of Several Series of Precious Metal Alloys," Physik. Z., 12, 1028-31, 1911.

287. Rudnitskii, A.A., "Thermoelectric Properties of the Noble Metals and Their Alloys," USAEC Rept. AEC-TR-3724, 233 pp., 1956.

288. Borelius, G., "Conductivity of Electricity in Alloys Containing Mixed Crystals," Ann. Physik, 4, 77(10), 109-37, 1925.

289. Elliott, R.P., Constitution of Binary Alloys, First Supplement, McGraw-Hill Book Co., New York, NY, 877 pp., 1965.

290. Grum-Grzhmailo, N.V., "Electrical Resistance and Hall Effect of Gold-Silver Alloys," J. Inorg. Chem., USSR, 1(9), 118-22, 1956.

291. Schulze, H.A. and Lücke, K., "Short-Range Order Formation in Dilute Alloys Due to Quenched-in Vacancies," J. Appl. Phys., 39, 4860-2, 1968.

292. Schulze, A. and Lücke, K., "The Influence of Vacancies on Short Range Order Formation in Au-Ag Alloys," Acta Met., 20, 529-42, 1972.

293. Lücke, K. and Haas, H., "The Resistivity Change During Short-Range Order Formation in a Au-15 At.% Ag Alloy," Scr. Met., 7, 781-6, 1973.

294. Cowley, J.M., "An Approximate Theory of Order in Alloys," Phys. Rev., 77(5), 669-75, 1950.

295. Giardina, M.D., Schüle, W., Frank, W., and Seeger, A., "Ordering Properties and Interpretation of Radiation Damage in Au-15 At.% Ag Alloys," Rad. Eff., 12, 277-80, 1972.

296. Schüle, W. and Crestoni, G., "Short-Range Order in Gold-Silver Alloys," Z. Metallkd., 66(12), 728-33, 1975.

297. Giauque, W.F. and Stout, J.W., "Low Temperature Resistance of Gold-Silver Alloys," J. Am. Chem. Soc., 60(1), 388-93, 1938.

298. Crisp, R.S. and Rungis, J., "Thermoelectric Power and Thermal Conductivity in the Silver-Gold Alloy System from 3-300°K," Phil. Mag., 22(176), 217-36, 1970.

299. Davis, T.H. and Rayne, J.A., "Specific Heat and Residual Resistivity of Binary and Ternary Noble-Metal Alloys," Phys. Rev., B6(8), 2931-42, 1972.

300. Boes, J., VanDam, A.J., and Bijovet, J., "Kondo Effect in the Electrical Resistivity of Silver-Gold Alloys with Ytterbium," Phys. Lett., 28A(2), 101-2, 1968.

301. Stewart, R.G. and Huebener, R.P., "Deviations from Matthiessen's Rule in Dilute Gold and Platinum Alloys," Phys. Rev., B1(8), 3323-38, 1970.

302. Iyer, V.K. and Asimow, R.M., "The Electrical Resistivity of Gold-Silver Alloys," J. Less-Common Metals, 13(1), 18-23, 1967.

303. Van der Sijde, B., "The Resistivity Changes Caused by Ordering in Some Quenched AuAg Alloys," Physica, 29(5), 559-61, 1963.

304. Dewar, J. and Fleming, J.A., "The Electrical Resistance of Metals and Alloys at Temperatures Approaching the Absolute Zero," Phil. Mag., 5, 36, 271-99, 1893.

305. Dawson, H.I., "Recovery of Point Defects in Cold Worked Au, Ag, and Cu," Acta Met., 13, 453-64, 1965.

306. Clay, J., "On the Change with Temperature of the Electrical Resistance of Alloys at Very Low Temperatures," Univ. Leiden, Comm. Phys. Lab. No. 107d, 30-51, 1908.

307. Weinberg, I., "Thermoelectric Power in Silver-Gold and Silver-Germanium Alloys," Phys. Rev., 157(3), 564-9, 1967.

308. Barber, A.J. and Caplin, A.D., "The Low Temperature Electrical Resistivity of High Purity Ag and Ag-Based Alloys," J. Phys. F: Metal Phys., 5, 679-96, 1975.

309. Sparks, L.L. and Hust, J.G., "Thermoelectric Voltage of Silver-28 Atomic Percent Gold Thermocouple Wire, SRM 733, versus Common Thermocouple Materials between Liquid Helium and Ice Fixed Points," NBS Spec. Publ. 260-34, 37 pp., 1972.

310. Van Baarle, C., Gorter, F.W., and Winsemius, P., "Thermal Conductivity and Thermopower of Silver and Silver-Base Alloys at Low Temperatures. III. Alloys with Gold, Antimony, and Palladium," Physica, 35(2), 223-40, 1967.

311. Howe, R.A. and Enderby, J.E., "The Thermoelectric Power of Liquid Silver-Gold," Phil. Mag., 16(149), 467-76, 1967.

312. Ricker, T., "Magnetic Properties of Silver Alloyed with Gold, Palladium, Cadmium, and Aluminum," Z. Metallk., 54(12), 718-24, 1963.

313. Beckmann, B., University of Uppsala, Ph.D. Thesis, 1911.

314. Broniewski, W. and Wesolowski, K., "Silver-Gold Alloys as Typical of Continuous Solid Solutions," Compt. Rend., 194, 2047-9, 1932.

315. Shimizu, Y., "The Magnetic Susceptibility of Several Systems of Binary Alloys," Tohoku Univ., Science Reports, 21, 826-50, 1932.

316. Linde, J.O., "An Experimental Study of the Resistivity-Concentration Dependence of Alloys," Helv. Phys. Acta, 41, 1007-15, 1968.

317. Strouhal, V. and Barus, C., "Electrical Resistivity of Gold-Silver Alloy," Abh. d. K. Böhm. Ges. d. Wiss., 6, 12, 1883.

318. Clay, J., "On the Change with Temperature of the Electrical Resistance of Alloys at Very Low Temperatures," Jahrb. d. Radioakt., 8, 399, 1911.

319. Auer, H., Riedl, E., and Seemann, H.J., "Magnetic, Electric, and Spectrographic Investigations upon Gold-Silver Alloys," Z. Physik, 92(5-6), 291-302, 1934.

320. Bridgman, P.W., "Compressibilities and Pressure Coefficients of Resistance of Certain Elements, Compounds, and Alloys," Proc. Am. Acad. Arts Sci., 68(2), 27-93, 1933.

321. Shunk, F.A., Constitution of Binary Alloys, Second Supplement, McGraw-Hill Book Co., New York, NY, 720 pp., 1969.

322. Jones, F.W. and Pumphrey, W.I., "Free Energy and Metastable States in the Iron-Nickel and Iron-Manganese Systems," J. Iron Steel Inst. London, 163, 121-31, 1949.

323. Machlin, E.S. and Cohen, M., "Burst Phenomenon in the Martensitic Transformation," Trans. AIME, 191, 746-54, 1951.

324. Machlin, E.S. and Cohen, M., "Isothermal Mode of Martensitic Transformation," Trans. AIME, 194, 489-500, 1952.

325. Fert, A. and Campbell, I.A., "Electrical Resistivity of Ferromagnetic Nickel and Iron Based Alloys," J. Phys. F, 6(5), 849-71, 1976.

326. Farrell, T. and Greig, D., "The Electrical Resistivity of Nickel and Its Alloys," J. Phys. C, Ser. 2, 1, 1359-69, 1968.

327. Schwerer, F.C. and Conroy, J.W., "Two-Current Conduction in Nickel-Base Alloys," J. Phys. F, 1(6), 877-92, 1971.

328. Schwerer, F.C. and Cuddy, L.J., "Spin Disorder Scattering in Iron-Base Alloys," J. Appl. Phys., 41(3), 1419-20, 1970.

329. Schwerer, F.C. and Cuddy, L.J., "Spin Disorder Scattering in Iron- and Nickel-Base Alloys," Phys. Rev. B, 2(6), 1575-86, 1970.

330. Shirakawa, Y., "On the Longitudinal Magnetoresistance Effect at Various Temperatures in Iron Nickel Alloys," Tohoku Imp. Univ., Sci. Repts., 27, 485-531, 1939.

331. Ascher, E.A., "Effet Hall, Aimantation Spontane'e at Temperature," Helv. Phys. Acta, 28(7), 667-93, 1955.

332. Ingersoll, L.R., et al., "Some Physical Properties of Nickel-Iron Alloys," Phys. Rev., 16, 126-32, 1920.

333. Reed, R.P., Clark, A.F., and Schramm, R.E., "Defect Annealing (4 to 295 K) after Martensitic Phase Transformation in an Iron-29 Nickel Alloy," Scr. Metall., 5(6), 485-8, 1971.

334. Livingston, H. and Mukherjee, K., "Martensitic Pretransformation Phenomena in the Gold 47.5 at.% Cadmium and the Iron-29.7 at.% Nickel Alloys," J. Appl. Phys., 43(12), 4944-50, 1972.

335. Armstrong, B.E. and Fletcher, R., "Resistivity and Thermopower of a Series of Nickel-Iron Invar Alloys," Can. J. Phys., 50(3), 244-50, 1972.

336. Gautier, F. and Loegel, B., "Electrical Resistivity of Concentrated Nickel Alloys," Solid State Commun., 11(9), 1205-8, 1972.

337. Mikhailova, G.N., "Thermal and Electrical Conductivity of Certain Technical Materials in the Temperature Range 0.4-1.5 K," Zh. Tekh. Fiz., 41(4), 800-3, 1971; Engl. transl.: Sov. Phys.-Tech. Phys., 16(4), 626-8, 1971.

338. Larikov, L.N., Usov, Yu.V., and Boychuk, I.N., "Temperature Dependences of the Electrical Resistivity of Iron-Nickel Alloys," Dopov. Akad. Nauk Ukr. SSR, Fiz. Mat. Tekh. Nauk, A(5), 464-6, 1977.

339. Kondorskii, E.I. and Sedov, V.L., "The Change of Atomic Magnetic Moments in Ferromagnetic Metals Under Hydrostatic Compression," Zh. Eksp. Teor. Fiz., 38, 773-9, 1960; Engl. transl.: Sov. Phys.-JETP, 11(3), 561-5, 1960.

340. Jellinghaus, W. and de Andrés, M.P., "Hall Effect and Conductivity of Iron-Nickel Alloys," Ann. Phys., 5(7), 187-99, 1960.

341. Kalinin, V.M., Danilov, M.A., Komarova, L.K., and Tseytlin, A.M., "Influence of Titanium on the Physical Properties of Iron-Nickel Invars," Fiz. Met. Metalloved., 36(2), 310-5, 1973; Engl. transl.: Phys. Met. Metallogr., 36(2), 75-80, 1973.

342. Window, B., "Invar Anomalies," J. Appl. Phys., 44(6), 2853-65, 1973.

343. Somura, T., "Magneto Volume Contribution to the Temperature Variation of the Magneto-Resistivity in Iron-Nickel Invar Alloys," J. Phys. Soc. Jpn., 42(3), 826-32, 1977.

344. Tanji, Y., Moriya, H., and Nakagawa, Y., "Anomalous Concentration Dependence of Thermoelectric Power of Iron-Nickel (fcc) Alloys at High Temperatures," J. Phys. Soc. Jpn., 45(4), 1244-8, 1978.

345. Källback, O., "Determination of the Order-Disorder Transition Point in 25% Iron - 75% Nickel," Arkiv. Matematik Astron. Fys., 34B(17), 1-6, 1947.

346. Moore, J.P., Kollie, T.G., Graves, R.S., and McElroy, D.L., "Thermal Transport Properties of Ordered and Disordered 75% Nickel - 25% Iron," J. Appl. Phys., 42(8), 3114-20, 1971.

347. Wakelin, R.J. and Yates, E.L., "A Study of the Order-Disorder Transformation in Iron-Nickel Alloys in the 25 Percent Iron Region," Proc. Phys. Soc. London, B66, Part 3, 221-40, 1953.

348. Szentirmay, Zs., "The Influence of Magnetic Annealing on the Transport Properties of Some Iron-Nickel Alloys," Acta Physica et Chimia Debricina, 20, 25-33, 1976.

349. Ono, Y. and Yagi, T., "Electrical Resistivity of Molten Iron-Nickel and Iron-Cobalt Alloys," Trans. Iron Steel Inst. Jpn., 12(4), 314-6, 1972.

350. Baum, B.A., Tyagunov, G.V., Gel'd, P.V., and Khasin, G.A., "Viscosity and Electrical Resistance of Iron-Nickel Melts," Izv. Vyssh. Uchebn. Zaved., Chern. Metall., 14(10), 5-8, 1971.

351. Epin, V.N., Baum, B.A., and Tyagunov, G.V., "Electrical Resistance of Iron-Nickel Alloys in Temperature Range 1200-1700°C," Izv. Vyssh. Uchebn. Zaved., Fiz., 20(7), 145-6, 1977; Engl. transl.: Sov. Phys. J., 20(7), 968-9, 1977.

352. Filippov, E.S. and Krestonikov, A.N., "Structural Transitions in Liquid Fe-Ni Alloys," Russ. Metall., 4, 112-4, 1969.

353. Burgess, C.F. and Aston, J., "The Electrical Resistance of Iron Alloys," Trans. Am. Electrochem. Soc., 20, 205, 1911.

354. Honda, K., "On the Thermal and Electrical Conductivities of Nickel Steels," Sci. Rep. Tohoku Imp. Univ., 7, 59-66, 1918.

355. Bridgman, P.W., "The Effect of Pressure on the Resistance of Three Series of Alloys," Proc. Amer. Acad. Arts Sci., 63, 329-45, 1928.

356. Bäcklund, N.G., "An Experimental Investigation of the Electrical and Thermal Conductivity of Iron and Some Dilute Iron Alloys at Temperatures Above 100°K," J. Phys. Chem. Solids, 20(1/2), 1-16, 1961.

357. Soffer, S., Dreesen, J.A., and Pugh, E.M., "Hall Effects, Resistivity, and Thermopower in Iron and Iron-Nickel Systems for x Equals 0 to 0.2," Phys. Rev., 140(2A), 668-75, 1965.

358. Cadeville, M.C. and Loegel, B., "Transport Properties in Concentrated Nickel-Iron Alloys at Low Temperatures," J. Phys. F, 3(7), L115-9, 1973.

359. Berger, L. and Rivier, D., "Electrical and Thermal Resistivity of Pure Nickel and of an Iron-Nickel Alloy in a Magnetic Field at Low Temperatures," Helv. Phys. Acta, 35(7-8), 715-32, 1962.

360. Kohlhaas, R. and Kierspe, W., "The Thermal Conductivity of Pure Iron and Some Ferritic and Austenitic Steels Between the Temperature of Liquid Air and Room Temperature," Arch. Eisenhuettenwes., 36(4), 301-9, 1965.

361. Griffiths, E., Powell, R.W., and Hickman, M.J., "Second Report of Subcommittee 'A', Thermal Treatment. 'Part 3. The Physical Properties of a Series of Steels I,'" Iron Steel Inst. (London) Spec. Rept., 24, 215-51, 1939.

362. Bungardt, K. and Spyra, W., "Thermal Conductivity of Alloyed and Plain Steels and Alloys at Temperatures Between 20 and 700°," Arch. Eisenhuettenwes., 36(4), 257-67, 1965.

363. Wotruba, K., "The connection Between the Coercive Force and the Initial Susceptibility of Plastically Deformed Ferromagnetics," Chek. Fiz. Zh., 7(5), 568-76, 1957.

364. "Alloys, Review of Properties," Wilbur B. Driver Co., Product Guide, 1966.

365. Smolin, M.D., "Temperature Dependence of the Resistivity of Metals in the Two-Zone Approximation," Fiz. Met. Metalloved., 21(4), 630-2, 1966; Engl. transl.: Phys. Met. Metallogr., 21, 148-9, 1966.

366. Matsumoto, G., Satoh, T., and Iida, S., "Dynamic Properties of Permalloy Thin Films," Phys. Soc. Jpn., 21(2), 231-7, 1966.

367. Broniewski, W. and Smolinski, J., "The Structure of Iron-Nickel Alloys," Compt. Rend., Acad. Sci. (Paris), 196, 1793-6, 1933.

368. Savitskii, E.M. and Pravoverov, N.L., "Kurnakov Phases in the Palladium-Silver System," Russ. J. Inorg. Chem., 6(2), 253-4, 1961.

369. Pravoverov, N.L. and Savitskii, E.M., "Effect of Alloying Additions on the Electrical Properties of the Tensometric Palladium-Silver Alloy PdS-35," Russ. J. Inorg. Chem., 7(6), 687-91, 1962.

370. Aarts, W.H. and Houston-MacMillan, A.S., "Anomalous Behavior of Ag-Pd on Plastic Deformation," Acta Metall., 5, 525-7, 1957.

371. Rao, K.K., "Electrical Resistivity Recovery in Cold-Worked 60 percent Silver - 40 percent Palladium Alloy," Acta Metall., 10(9), 900, 1962.

372. Chen, W.K. and Nicholson, M.E., "The Influence of Annealing on the Electrical Properties of Cold-Worked Silver-Palladium Alloys," Acta Metall., 12(6), 687-96, 1964.

373. Westerlund, R.W. and Nicholson, M.E., "Effect of Plastic Deformation on the Resistivity and Hall Constant of Silver-Palladium Alloys," Acta Metall., 14(5), 569-74, 1966.

374. Chen, W.K. and Nicholson, M.E., "Reply to Resistivity Recovery Stages in a Silver-41.8 Weight Percent Palladium Alloy," J. Appl. Phys., 39(7), 3496-7, 1968.

375. Rao, C.N. and Rao, K.K., "Effect of Temperature on the Lattice Parameters of Silver-Palladium Alloys," Can. J. Phys., 42(7), 1336-42, 1964.

376. Kemp, W.R.G., Klemens, P.G., Sreedhar, A.K., and White, G.K., "The Thermal and Electrical Conductivity of Silver-Palladium and Silver-Cadmium Alloys at Low Temperatures," Proc. R. Soc., A233, 480-93, 1956.

377. Mott, N.F., "Electrons in Transition Metals," Adv. Phys., 13(51), 325-422, 1964.

378. Ricker, T. and Pflüger, E., "Temperature Dependence of Resistivity and Other Electrical Properties of Palladium Silver and Palladium Rhodium Alloys," Z. Metallkd., 57(1), 39-45, 1966.

379. Murani, A.P., "Localized Enhancement Effects in Pd-Ag Alloys," Phys. Rev. Letters, 33(2), 91-4, 1974.

380. Edwards, L.R., Chen, C.W., and Legvold, S., "Resistivity Minima in Pd-Ag and Pd-Au Alloys," Solid State Commun., 8(17), 1403-5, 1970.

381. Chen, C.W., Edwards, L.R., and Legvold, S., "Resistance Anomoly in Palladium-Silver Alloys Containing Rare Earth Impurities," Phys. Status Solidi, 26(2), 611-9, 1968.

382. Greig, D. and Rowlands, J.A., "The T^2 Electrical Resistivity in Nickel and Palladium Alloys," J. Phys. F, 4, 232-45, 1974.

383. Greig, D. and Rowlands, J.A., "Resistance Minima and Deviations from Matthiessen's Rule in Dilute Palladium Alloys," J. Phys. F, 4, 536-49, 1974.

384. Arajs, S., Rao, K.V., Yao, Y.D., Teoh, W., "Electrical Resistivity of Palladium-Silver Alloys at High Temperatures," Private Communication from Rao, K.V., 1977.

385. Pravoverov, N.L. and Tribunskaya, I.A., "Properties of Silver Alloys Containing Small Amounts of Palladium and Cadmium," Russ. Metall., 1, 75-8, 1967.

386. Dewar, J. and Fleming, J.A., "On the Electrical Resistance of Pure Metals, Alloys, and Non-Metals at the Boiling Point of Oxygen," Philos. Mag., 34, 326-37, 1892.

387. Sarachik, M.D., "Resistivity of the 4d Transition Series Ru-Rh-Pd-Ag Containing Fe," J. Appl. Phys., 39(2), 699-701, 1968.

388. Seemann, H.J. and Rennollet, G., "Studies of the Silver-Palladium Mixed Crystal Series by Means of Hall Effect and Electrical Conductivity," Z. Phys., 196(5), 486-94, 1966.

389. Geibel, W., "On Several Electrical and Mechanical Properties of Noble Metal Alloys. II," Z. Anorg. Chem., 70, 240-54, 1911.

390. Greig, D. and Livesey, D., "The Hall Coefficient of Dilute Palladium and Platinum Alloys," J. Phys. F, 2, 699-708, 1972.

391. Zwingmann, G., "Several Electrical and Mechanical Properties of Binary Palladium Alloys. I. Palladium Alloys With Elements of the Second Large Period," Z. Metallkd., 54(5), 286-92, 1963.

392. Simon, P.R.F., "Resistivity and Thermoelectric Power of Silver-Palladium Alloys," in Proc. 9th Int. Conf. on Low Temp. Phys., Part B, Plenum Press, New York, 1045-9, 1965.

393. Guénault, A.M., "Low-Temperature Thermoelectric Power of Palladium-Silver Alloys," Philos. Mag., 30(3), 641-9, 1974.

394. Carson, A.W., Lewis, F.A., and Schurter, W.H., "Relationships Between the Hydrogen Content and Electrical Resistance of Palladium + Silver Alloys," Trans. Faraday Soc., 63, 1447-52, 1966.

395. Szafranski, A.W., "Electrical Resistance of the Palladium-Silver-Hydrogen Alloys From 4 to 300 K," Phys. Status Solidi, 19A(2), 459-66, 1973.

396. Couper, A. and Metcalfe, A., "Electrical Resistivity of Silver-Palladium Alloys," J. Phys. Chem., 70(6), 1850-3, 1966.

397. Rao, K.V., Rapp, Ö., Johanneson, C., and Aström, H.U., "Electrical Resistivit of Fe Dissolved in Pd-Ag Matrix Alloys," Physica B, Proc. 1976 Int. Conf. Magnetism, 1977.

398. Krüger, F. and Gehm, G., "Electrical Resistivity of Silver-Palladium Alloys," Ann. Phys., 16(5), 190-202, 1933.

399. Touloukian, Y.S., Powell, R.W., Ho, C.Y., and Klemens, P.G., Thermal Conductivity - Metallic Elements and Alloys, Vol. 1 of Thermophysical Properties of Matter - The TPRC Data Series, IFI/Plenum Data Corp., New York, 1595 pp., 1970.

400. Laws, F.A., Electrical Measurements, 2nd Edition, McGraw-Hill Book Co., Inc., New York, 739 pp., 1938.

401. Harris, F.K., Electrical Measurements, John Wiley and Sons, Inc., New York, 784 pp., 1952.

402. Van der Pauw, L.J., "A Method of Measuring Specific Resistivity and Hall Effect of Discs of Arbitrary Shape," Philips Res. Rep., 13, 1-9, 1958.

403. Van der Pauw, L.J., "A Method of Measuring the Resistivity and Hall Coefficient on Lamellae of Arbitrary Shape," Philips Tech. Rev., 20(8), 220-4, 1958-9.

404. Chambers, R.G. and Park, J.G., "Measurement of Electrical Resistivity by a Mutual Inductance Method," Brit. J. Appl. Phys., 12, 507-10, 1961.

405. Zimmerman, J.E., "Measurement of Electrical Resistivity of Bulk Metals," Rev. Sci. Instrum., 32(4), 402-5, 1961.

406. Radenac, A., Lacoste, M., and Roux, C., "Apparatus Meant for the Measurement of the Electrical Resistivity of Metals and Alloys by the Method of the Rotating Field Up to About 2000 K," Rev. Int. Hautes Temper. Refract., 7(4), 389-96, 1970.

407. Cezairliyan, A. and McClure, J.L., "Thermophysical Measurements on Iron Above 1500 K, Using a Transient (Subsecond) Technique," J. Res. Nat. Bur. Stand., 78A(1), 1-4, 1974.

408. Bean, C.P., DeBlois, R.W., and Nesbitt, L.B., "Eddy-Current Methods for Measuring the Resistivity of Metals," J. Appl. Phys., 30, 1976-80, 1959.